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16. ABSTRACT

Standards of performance for the control of particulate matter emissions from affected facilities at new and modified lime manufacturing plants are being proposed under the authority of sections 111, 114, and 301(a) of the Clean Air Act, as amended. The standards would require that particulate matter emissions be reduced by over 99 percent below the uncontrolled levels, and by about 70 percent below the emission levels being achieved by existing sources controlled to meet typical state standards. Volume 1 discusses the proposed standards, and an analysis of the associated environmental and economic impacts is included in this document. Volume 2, which will be published when the standards are promulgated, will contain a summary of the public comments on the proposed standards and EPA's responses. A discussion of any differences between the proposed and promulgated standards will also be included.

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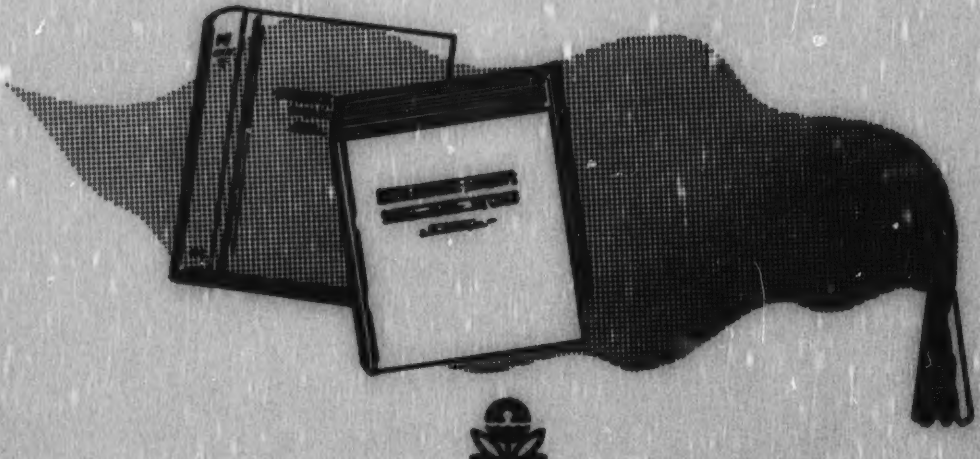

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Emission Standards and Engineering Division

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Lime Manufacturing Plants

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1. SUMMARY

1.1 PROPOSED STANDARDS

Standards of performance for new and modified rotary lime kilns and hydrators at lime manufacturing plants are being proposed under the authority of section 111 of the Clean Air Act. The standards require the control of particulate emissions from the specified affected facilities. These facilities account for virtually all of the particulate emissions at lime plants. A summary of the proposed standards and monitoring requirements is presented in Table 1-1. Preceding the act of proposal has been the Administrator's determination that emissions from lime plants contribute to the endangerment of public health or welfare. In accordance with section 117 of the Act, proposal of the standards was preceded by consultation with appropriate advisory committees, independent experts, industry representatives, and Federal departments and agencies.

The proposed standards for the rotary lime kiln limit emissions to 0.15 kilogram of particulate matter per megagram of limestone feed (0.3 lb/ton) and 10 percent opacity. These standards are based on the results of EPA source tests at six lime plants. The data are summarized in Appendix C. The owner or operator of the affected facility will be required to continuously monitor the opacity of the emission plume. When a wet scrubber is used for control, the opacity monitoring requirement is waived, and the pressure drop and liquid supply pressure of the scrubber must be monitored instead.

The proposed standards for the lime hydrator limits the emissions to 0.075 kilogram of particulate matter per megagram of lime feed (0.15 lb/ton).

Table 1-1. SUMMARY OF PROPOSED STANDARDS AND MONITORING REQUIREMENTS

Affected Facility	Particulate Control Device	Particulate Standard(a)		Opacity Standard	Monitoring Requirements
		kg/Mg	lb/ton		
1. Lime Kiln	Baghouse	0.15	0.3	10%	Opacity
	Electrostatic Precipitator	0.15	0.3	10%	Opacity
	Scrubber	0.15	0.3	N/A[b]	Scrubber pressure drop and liquid supply pressure
2. Hydrator	Scrubber	0.075	0.15	None	Fluid flow rate and fan electric current

[a] The proposed standards are in the metric units kilogram per megagram of feed (kg/Mg).
[b] The opacity standard does not apply if a scrubber is used to control particulate matter from the lime kiln.

No opacity standard is being proposed for the hydrator. The proposed particulate standard is based on the results of EPA source tests on two hydrator facilities. The data are summarized in Appendix C. The proposed standards also require that the pressure drop and the liquid supply pressure of the scrubber used to control the emissions must be monitored.

1.2 ENVIRONMENTAL IMPACT

The beneficial and adverse environmental impacts associated with the proposed standards and with the various emission control alternatives that were considered in selecting the standards are presented in this section. The impacts are discussed in detail in Chapter 6, Environmental Impact, and in Chapter 7, Economic Impact. A cross reference between the EPA guidelines for the preparation of Environmental Impact Statements and this document is included in Appendix B.

Table 1-2 is a matrix summarizing the environmental, economic, and inflationary impacts that have been considered. Although the quantified values presented are somewhat subjective, the table presents the type and relative magnitude of the impacts.

For the lime kiln, alternative C is the baseline system upon which the impacts associated with the other alternatives are measured. Alternatives A-1, A-2, B-1, and B-2 are combinations of the various control levels for particulate matter and SO_2 that have been considered. Alternative A represents the use of a dry control system, such as a baghouse or an ESP, to control particulate emissions from the lime kiln. A-1 requires high efficiency control and A-2 requires medium efficiency control. Alternative B represents the use of a scrubber to control both particulate matter and SO_2 from the kiln. Both B-1 and B-2 require control of SO_2 emissions to a concentration of 100 parts per million. B-1 requires high efficiency particulate control and B-2 requires medium efficiency particulate control.

Table 1-2. MATRIX OF THE ENVIRONMENTAL AND ECONOMIC IMPACTS OF THE ALTERNATIVE STANDARDS FOR THE LIME KILN AND THE HYDRATOR

Facility and Alternative	Air Impacts	Water Impacts	Solid Waste Impacts	Energy Impacts	Noise and Radiation Impacts	Economic Impacts	Inflationary Impacts
LIME KILN							
A1	+4	0	-2	+1	0	-1	0
A2	+3	0	-2	+1	0	-1	0
B1	+4	0	-3	-2	0	-2	0
B2	+3	0	-3	-2	0	-2	0
C	0	0	0	0	0	0	0
HYDRATOR							
I	+4	0	-1	-1	0	-1	0
II	0	0	0	0	0	0	0

KEY:
+ Beneficial Impact
- Adverse Impact

0 No Impact
1 Negligible Impact
2 Small Impact
3 Moderate Impact
4 Large Impact

The impacts on air quality are beneficially large for alternatives A-1 and B-1. Significant negative impacts on water, energy demand, and solid waste occur under alternatives B-1 and B-2. There are no known noise or radiation impacts associated with any of the alternatives considered for the lime kiln.

For the hydrator unit, there were only two alternatives considered: alternative I, the proposed standard, and alternative II, the baseline system. Significant reduction in particulate emissions occur under alternative I, with only negligible impacts on energy demand. No incremental impacts on water or solid waste are anticipated. There are no known noise or radiation impacts associated with either the alternatives considered for the hydrator.

1.3 INFLATION IMPACT

The costs associated with the proposed standards for new and modified facilities at lime plants have been judged not to be of such magnitude to require an analysis of the inflationary impact. Screening criteria have been developed by EPA to be used in the impact analysis. These criteria have been outlined in an Agency publication and include:

(1) National annualized cost of compliance.

(2) Total added production cost in relation to sales price.

(3) Net national energy consumption increase.

(4) Added demands or decreased supplies of selected materials.

Should any of the guideline values listed under these criteria be exceeded, a full inflationary impact assessment would be required.

1.4 CAPACITY AND COST IMPACT

The proposed standards will impact an estimated 6.8 teragrams (7.5×10^6 tons) of lime manufacturing capacity through 1982. It is projected that the equivalent of 10 new and modified rotary lime kilns and 1 new lime hydrator will be affected per year through 1982. The industry-wide investment costs for control of particulate emissions from these facilities through 1982 are projected to be approximately $3.18 million. The fifth-year incremental annualized costs, including depreciation and interest, are estimated at approximately $4.97 million.

The Environmental Protection Agency has determined that this document does not contain a major proposal requiring preparation of an Economic Impact Analysis under Executive Orders 11821 and 11949 and OMB Circular A-107.

2. INTRODUCTION

Standards of performance under section 111 of the Clean Air Act are proposed following a detailed investigation of air pollution control methods available to the affected industry and the impact of their costs on the industry. This document summarizes the information obtained from such a study of the lime manufacturing industry. Its purpose is to explain in detail the background and basis of the proposed standards and to facilitate analysis of the proposed standards by interested persons, including those who may not be familiar with the many technical aspects of the industry. To obtain additional copies of this document or the Federal Register notice of proposed standards, write to Public Information Center (PM-215), the Environmental Protection Agency, Washington, D. C. 20460 (specify Standards Support and Environmental Impact Statement, Volume 1: Proposed Standards of Performance for Lime Manufacturing Plants.)

2.1 AUTHORITY FOR THE STANDARDS

Standards of performance for new stationary sources are developed under section 111 of the Clean Air Act (42 U.S.C. 1857c-6), as amended in 1970. Section 111 requires the establishment of standards of performance for new stationary sources of air pollution which ". . . may contribute significantly to air pollution which causes or contributes to the endangerment of public health or welfare." The Act requires that standards of performance for such sources reflect ". . . the degree of emission limitation achievable through the application of the best system of emission reduction which (taking into account the cost of achieving such reduction) the Administrator determines has been adequately demonstrated." The standards apply only to stationary sources, the construction or modification of which commences after regulations are proposed by publication in the Federal Register.

Section 111 prescribes three steps to follow in establishing standards of performance.

1. The Administrator must identify those categories of stationary sources for which standards of performance will ultimately be promulgated by listing them in the Federal Register.
2. The regulations applicable to a category so listed must be proposed by publication in the Federal Register within 120 days of its listing. This proposal provides interested persons an opportunity for comment.
3. Within 90 days after the proposal, the Administrator must promulgate standards with any alterations he deems appropriate.

Standards of performance, by themselves, do not guarantee protection of health or welfare; that is, they are not designed to achieve any specific air quality levels. Rather, they are designed to reflect best demonstrated technology (taking into account costs) for the affected sources. The overriding purpose of the collective body of standards is to maintain existing air quality and to prevent new pollution problems from developing.

Previous legal challenges to standards of performance have resulted in several court decisions[1,2] of importance in developing future standards. In those cases, the principal issues were whether EPA: (1) made reasoned decisions and fully explained the basis of the standards, (2) made available to interested parties the information on which the standards were based, and (3) adequately considered significant comments from interested parties.

Among other things, the court decisions established: (1) that preparation of environmental impact statements is not necessary for standards developed under section 111 of the Clean Air Act because, under that section, EPA must consider any counter-productive environmental effects of a standard in determining what system of control is "best;" (2) in considering costs it is not necessary to provide a cost-benefit analysis; (3) EPA is not required to justify standards that require different levels of control in different industries unless such different standards may be unfairly discriminatory; and (4) it is sufficient for EPA to show that a standard can be achieved rather than that it has been achieved by existing sources.

Promulgation of standards of performance does not prevent State or local agencies from adopting more stringent emission limitations for the same sources. On the contrary, section 116 of the Act (42 USC 1857-D-1) makes clear that States and other political subdivisions may enact more restrictive standards. Furthermore, for heavily polluted areas, more stringent standards may be required under section 110 of the Act (42 USC 1857c-5) in order to attain or maintain national ambient air quality standards prescribed under section 109 (42 USC 1857c-4). Finally, section 116 makes clear that a State may not adopt or enforce less stringent new source standards than those adopted by EPA under section 111.

Although standards of performance are normally structured in terms of numerical emission limits where feasible,[1] alternative approaches are sometimes necessary. In some cases physical measurement of emissions from a new source may be impractical or exorbitantly expensive. For example, emissions of hydrocarbons from storage vessels for petroleum liquids are greatest during tank filling. The nature of the emissions (high concentrations for short periods during filling and low concentrations for longer periods during storage) and the configuration of storage tanks make direct emission measurement impractical. Therefore, a more practical approach to standards of performance for storage vessels has been equipment specification.

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[1] "'Standards of performance,' . . . refers to the degree of emission control which can be achieved through process changes, operation changes, direct emission control, or other methods. The Secretary [Administrator] should not make a technical judgment as to how the standard should be implemented. He should determine the achievable limits and let the owner or operator determine the most economical technique to apply." Senate Report 91-1196.

2.2 SELECTION OF CATEGORIES OF STATIONARY SOURCES

Section 111 directs the Administrator to publish and from time to time revise a list of categories of sources for which standards of performance are to be proposed. A category is to be selected ". . . if [the Administrator] determines it may contribute significantly to air pollution which causes or contributes to the endangerment of public health or welfare."

Since passage of the Clean Air Amendments of 1970, considerable attention has been given to the development of a system for assigning priorities to various source categories. In brief, the approach that has evolved is as follows. Specific areas of interest are identified by considering the broad strategy of the Agency for implementing the Clean Air Act. Often, these "areas" are actually pollutants which are primarily emitted by stationary sources. Source categories which emit these pollutants are then evaluated and ranked by a process involving such factors as (1) the level of emission control (if any) already required by State regulations; (2) estimated levels of control that might result from standards of performance for the source category; (3) projections of growth and replacement of existing facilities for the source category; and (4) the estimated incremental amount of air pollution that could be prevented, in a preselected future year, by standards of performance for the source category. An estimate is then made of the time required to develop a standard. In some cases, it may not be feasible to develop a standard immediately for a source category with a high priority. This might occur because a program of research and development is needed to develop control techniques or because techniques for sampling and measuring emissions may require refinement. The schedule of activities must also consider differences in the time required to complete the necessary investigation for different source categories. Substantially more time may be necessary, for example, if a number of pollutants must be investigated in a single source category. Further, even late in the development process the schedule for completion of a standard may change. For example, inability to obtain emission data from well-controlled sources in time to pursue the development process in a systematic fashion may force a change in scheduling.

Selection of the source category leads to another major decision: determination of the types of facilities within the source category to which the standard will apply. A source category often has several facilities that cause air pollution. Emissions from some of these facilities may be insignificant or very expensive to control. An investigation of economics may show that, within the costs that an owner could reasonably afford, air pollution control is better served by applying standards to the more severe pollution problems. For this reason (or perhaps because there may be no adequately demonstrated system for controlling emissions from certain facilities), standards often do not apply to all sources within a category. For similar reasons, the standards may not apply to all air pollutants emitted by such sources. Consequently, although a source category may be selected to be covered by a standard of performance, not all pollutants or facilities within that source category may be covered by the standards.

2.3 PROCEDURE FOR DEVELOPMENT OF STANDARDS OF PERFORMANCE

Congress mandated that sources regulated under section 111 of the Clean Air Act be required to utilize the best system of air pollution control (considering costs) that has been adequately demonstrated at the time of their design and construction. In so doing, Congress sought to:

1. Maintain existing high-quality air,
2. Prevent new air pollution problems, and
3. Ensure uniform national standards for new facilities.

Standards of performance, therefore, must (1) realistically reflect best demonstrated control practice; (2) adequately consider the cost of such control; (3) be applicable to existing sources that are modified as well as new installations; and (4) meet these conditions for all variations of operating conditions being considered anywhere in the country.

The objective of a program for development of standards is to identify the best system of emission reduction which "has been adequately demonstrated (considering cost)." The legislative history of section 111 and the court decisions referred to earlier make clear that the Administrator's judgment of what is adequately demonstrated is not limited to systems that are in actual routine use. Consequently, the search may include a technical assessment of control systems which have been adequately demonstrated but for which there is limited operational experience. In most cases, determination of the "degree of emission limitation achievable" is based on results of tests of emissions from existing sources. This has required worldwide investigation and measurement of emissions from control systems. Other countries with heavily populated, industrialized areas have sometimes developed more effective systems of control than those used in the United States.

Since the best demonstrated systems of emission reduction may not be in widespread use, the data base upon which standards are developed may be somewhat limited. Test data on existing well-controlled sources are obvious starting points in developing emission limits for new sources. However, since the control of existing sources generally represents retrofit technology or was originally designed to meet an existing State or local regulation, new sources may be able to meet more stringent emission standards. Accordingly, other information must be considered and judgment is necessarily involved in setting proposed standards.

Since passage of the Clean Air Amendments of 1970, a process for the development of a standard has evolved. In general, it follows the guidelines below.

1. Emissions from existing well-controlled sources are measured.
2. Data on emissions from such sources are assessed with consideration of such factors as: (a) the representativeness of the source tested (feedstock, operation, size, age, etc.); (b) the age and maintenance of the control equipment tested (and possible degradation in the efficiency of control of similar new equipment even with good maintenance procedures); (c) the design uncertainties for the type of control equipment being considered; and (d) the degree of uncertainty that new sources will be able to achieve similar levels of control.
3. During development of the standards, information from pilot and prototype installations, guarantees by vendors of control equipment, contracted (but not yet constructed) projects, foreign technology, and published literature are considered, especially for sources where "emerging" technology appears significant.
4. Where possible, standards are developed which permit the use of more than one control technique or licensed process.

5. Where possible, standards are developed to encourage (or at least permit) the use of process modifications or new processes as a method of control rather than "add-on" systems of air pollution control
6. Where possible, standards are developed to permit use of systems capable of controlling more than one pollutant (for example, a scrubber can remove both gaseous and particulate matter emissions, whereas an electrostatic precipitator is specific to particulate matter).
7. Where appropriate, standards for visible emissions are developed in conjunction with concentration/mass emission standards. The opacity standard is established at a level which will require proper operation and maintenance of the emission control system installed to meet the concentration/mass standard on a day-to-day basis, but not require the installation of a control system more efficient or expensive than that required by the concentration/mass standard. In some cases, however, it is not possible to develop concentration/mass standards, such as with fugitive sources of emissions. In these cases, only opacity standards may be developed to limit emissions.

2.4 CONSIDERATION OF COSTS

Section 111 of the Clean Air Act requires that cost be considered in developing standards of performance. This requires an assessment of the possible economic effects of implementing various levels of control technology in new plants within a given industry. The first step in this analysis requires the generation of estimates of installed capital costs and annual operating costs for various demonstrated control systems, each control system alternative having a different overall control capability. The final step in the analysis is to determine the economic impact of the various control alternatives upon a new plant in the industry.

The fundamental question to be addressed is whether or not a new plant would be constructed if a certain level of control costs would be incurred. Other issues that are analyzed are the effects of control costs upon product prices and product supplies, and producer profitability.

The economic impact upon an industry of a proposed standard is usually addressed both in absolute terms and by comparison with the control costs that would be incurred as a result of compliance with typical existing State control regulations. This incremental approach is taken since a new plant would be required to comply with State regulations in the absence of a Federal standard of performance. This approach requires a detailed analysis of the impact upon the industry resulting from the cost differential that exists between a standard of performance and the typical State standard.

The costs for control of air pollutants are not the only costs considered. Total environmental costs for control of water pollutants as well as air pollutants are analyzed wherever possible.

A thorough study of the profitability and price-setting mechanisms of the industry is essential to the analysis so that an accurate estimate of potential adverse economic impacts can be made. It is also essential to know the capital requirements placed on plants in the absence of Federal standards of performance so that the additional capital requirements necessitated by these standards can be placed in the proper perspective. Finally, it is necessary to recognize any constraints on capital availability within an industry as this factor also influences the ability of new plants to generate the capital required for installation of the additional control equipment needed to meet the standards of performance.

2.5 CONSIDERATION OF ENVIRONMENTAL IMPACTS

Section 102(2)(c) of the National Environmental Policy Act (NEPA) of 1969 (PL 91-190) requires Federal agencies to prepare detailed environmental statements on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. The objective of NEPA is to build into the decision-making process of Federal agencies a careful consideration of all environmental aspects of proposed actions.

As mentioned earlier, in a number of legal challenges to standards of performance for various industries, the Federal Courts of Appeals have held that environmental impact statements need not be prepared by the Agency for proposed actions under section 111 of the Clean Air Act. Essentially, the Federal Courts of Appeals have determined that "...the best system of emission reduction," "...require(s) the Administrator to take into account counter-productive environmental effects of a proposed standard, as well as economic costs to the industry..." On this basis, therefore, the Courts "...established a narrow exemption from NEPA for EPA determinations under section 111."[1,2]

In addition to these judicial determinations, the Energy Supply and Environmental Coordination Act (ESECA) of 1974 (PL-93-319) specifically exempted proposed actions under the Clean Air Act from NEPA requirements. According to section 7(c)(1), "No action taken under the Clean Air Act shall be deemed a major Federal action significantly affecting the quality of the human environment within the meaning of the National Environmental Policy Act of 1969."

The Agency has concluded, however, that the preparation of environmental impact statements could have beneficial effects on certain regulatory actions. Consequently, while not legally required to do so by section 102(2)(c) of NEPA, environmental impact statements will be prepared for various regulatory actions, including standards of performance developed under section 111 of the Clean Air Act. This voluntary preparation of environmental impact statements, however, in no way legally subjects the Agency to NEPA requirements.

To implement this policy, therefore, a separate section is included in this document which is devoted solely to an analysis of the potential environmental impacts associated with the proposed standards. Both adverse and beneficial impacts in such areas as air and water pollution, increased solid waste disposal, and increased energy consumption are identified and discussed.

2.6 IMPACT ON EXISTING SOURCES

Standards of performance may affect an existing source in either of two ways. Section 111 of the Act defines a new source as "any stationary source, the construction or modification of which is commenced after the regulations are proposed." Consequently, if an existing source is modified after proposal of the standards, with a subsequent increase in air pollution, it is subject to standards of performance. [Amendments to the general provisions of Subpart A of 40 CFR Part 60 to clarify the meaning of the term modification were promulgated in the Federal Register on December 16, 1975 (40 FR 58416).]

Secondly, promulgation of a standard of performance requires States to establish standards of performance for existing sources in the same industry under section 111(d) of the Act if the standard for new sources limits emissions of a pollutant for which air quality criteria have not been issued under section 108 or which has not been listed as a hazardous pollutant under section 112. If a State does not act, EPA must establish such standards. [General provisions outlining procedures for control of existing sources under section 111(d) have been promulgated on November 17, 1975 as Subpart B of 40 CFR Part 60 (40 FR 53340).]

2.7 REVISION OF STANDARDS OF PERFORMANCE

Congress was aware that the level of air pollution control achievable by any industry may improve with technological advances. Accordingly, section 111 of the Act provides that the Administrator may revise such standards from time to time. Although standards proposed and promulgated by EPA under section 111 are designed to require installation of the ". . . best system of emission reduction . . . (taking into account the cost). . ." the standards will be reviewed periodically. Revisions will be proposed and promulgated as necessary to assure that the standards continue to reflect the best systems that become available in the future. Such revisions will not be retroactive but will apply to stationary sources constructed or modified after proposal of the revised standards.

REFERENCES FOR CHAPTER 2

1. Portland Cement Association vs. Ruckelshaus, 486 F. 2nd 375 (D.C. Cir. 1973).

2. Essex Chemical Corp. vs. Ruckelshaus, 486 F 2nd 427 (D.C. Cir. 1973).

CHAPTER 3. THE LIME INDUSTRY

3.1 GENERAL

In the United States, the annual production of limestone ranks second to sand and gravel in tonnage of all commodities, and in physical volume exceeds such large tonnage materials as petroleum, coal, and iron ore. Since lime exists in varying amounts in nearly every country, annual world production is virtually incalculable but has been variously estimated at 2-2.5 billion tons in the 1960's.[1] Lime is the world's leading reagent for use in the treatment of both water and air pollution, and is the second largest basic chemical in commercial use.[2]

Deposits of limestone exist in every state in the U.S. and usually are found in very large amounts. It is estimated that 15-20 percent of the physical surface of the U.S. is underlayed with limestone. It should be noted that even though these deposits are extensive, they are frequently so overburdened that quarrying or mining is not economical. Because product quality is of high concern, only a small proportion of the total limestone production is of a grade suitable to meet the requirements demanded by industrial processes. The lower-grade limestones are generally suitable for use in the agricultural and building fields where the chemical composition is not a limiting factor in their use. The total production capacity of United States lime plants is about 22 million tons per year (1975), produced in 179 lime plants in over 40 states. From the past trends in lime usage and anticipated increase in the uses of lime, an annual growth rate of 5 percent is expected over the next ten years. Most of the production (80 percent) and anticipated growth in production will occur in lime plants that have over 100,000 tons per year production capacities.

There is one known lime plant in the U.S. where lime is derived from the calcination of oyster shells obtained from coastal waters. The dredging of oyster shells is concentrated in the Texas-Louisiana gulf area where no limestone deposits of consequence are found within 200 miles of the coast.

The four traditional major uses of lime are in agriculture, construction, chemical and metallurgical processes, and refractory applications. In 1974, chemical and metallurgical processes accounted for 81 percent of all lime consumption; construction uses for 10 percent; refractory application for 8 percent; and agricultural uses for only one percent.[3]

The lime industry has steadily become more capital intensive, producing more lime with less labor per unit of output. Table 3-1 shows the employment in the mines and plants of the lime industry in recent years.

Table 3.1 EMPLOYMENT IN THE LIME INDUSTRY IN RECENT YEARS[3]

Year	1970	1971	1972	1973	1974 (est.)
Employment	8,100	6,777	7,000	7,300	7,500

Although not a major employer, the lime industry is economically essential because many other basic industrial processes rely on the use of lime. Curtailment of future growth or the inability to supply changing lime markets would have a large multiplier effect on U.S. employment. However, these developments appear unlikely as large capital productive companies enter the picture as captive or commercial producers of lime.

3.2 PROCESSES AND THEIR EMISSIONS

The basic processes in production of lime are (1) quarrying the limestone raw material, (2) preparing the limestone for kilns by crushing and sizing, (3) calcining the limestone, and (4) processing the quicklime further by hydration. The quarrying, crushing and sizing of limestone is being considered in another document. The processes covered in the proposed standards are the calcination and hydration of the lime product. These are shown schematically in Figure 3-1. For the purposes of this document, "limestone" is considered to mean both calcitic and dolomitic limestone. The pertinent emissions are particulates from the kiln and hydrator and sulfur dioxide from the calcining process in the kilns.

3.2.1 Calcination and Its Emissions

Limestone is subjected to temperatures of about 1100°C (2000°F) to break it down chemically to produce quicklime and release CO_2. The reaction can be shown as follows:

$$CaCO_3 \rightarrow CaO + CO_2$$

Calcining at this temperature produces a soft, porous, highly reactive lime. Heating beyond this stage can result in lumps of inert, semi-vitrified material. This unreactive material is known as over-burned or dead-burned lime and is often used in the manufacture of refractory materials. If the raw material is not calcined sufficiently, lumps of calcium carbonate are left in the finished product. This is known as "underburned" lime.

In the United States, calcination is done in a variety of kilns including the long rotary kiln, the short rotary kiln with external stone preheater, the vertical or shaft kiln, the rotary hearth or Calcimatic kiln, and the fluidized bed kiln. Each type has its own advantages but the U.S. lime industry apparently

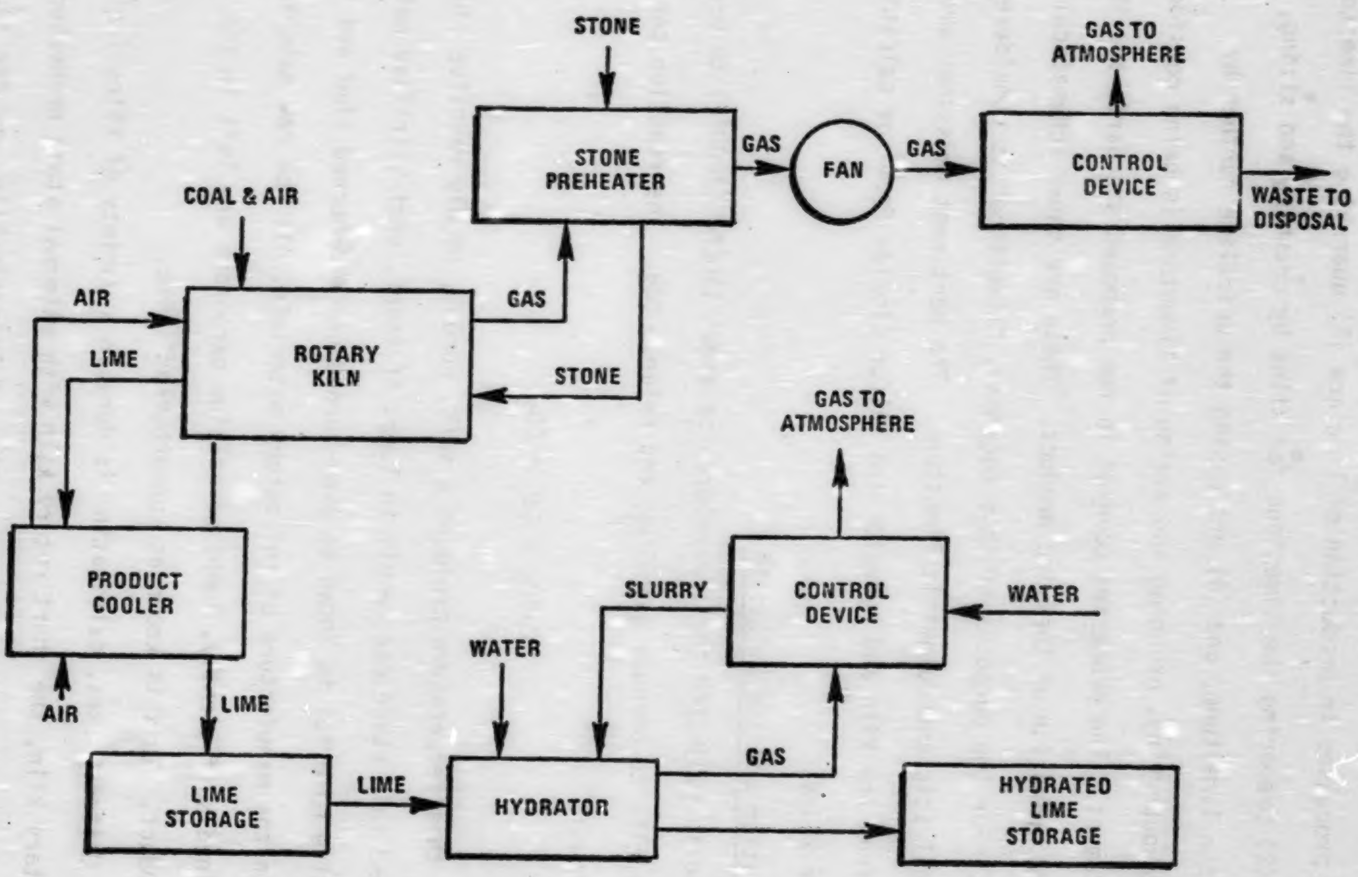

Figure 3-1. Flowsheet for modern lime calcination and hydration.

favors rotary kilns. Almost 90 percent of the U.S. lime production is processed in rotary kiln systems.[4] Virtually all kilns built in 1974-1975 were rotary kilns and this trend is expected to continue in the future.[5] One factor that makes the rotary kiln attractive for processing lime in the future is that it is the only kiln that can presently use coal and still maintain product quality.[6]

As natural gas and oil have become more expensive or unavailable, many plants using rotary kilns have modified their kilns to use coal. It is expected that the supply of low sulfur coal will not be able to meet the increased demand, and inevitably many plants will be forced to use high sulfur content coal. It is estimated that by 1986, 50 percent of the lime plant new capacity will have high sulfur coal as the only fuel available.

3.2.1.1 Rotary Kiln -

The operation of long and short rotary kilns is basically identical. These kilns are a furnace made of heavy steel plate lined with refractory brick. They are fired by one or combination of any of three available fuels: natural gas, pulverized coal, or oil. The largest kiln now in operation in the U.S. has a production capacity of almost 1000 tons of lime per day. Kilns vary in size, ranging from about 2 to almost 5 meters in diameter and from 18 to 137 meters in length.

The kilns are installed at a 3-5° inclination on four or six foundation piers and revolve on trunnions at 30-50 sec/revolution. Limestone is fed into the elevated end of the kiln and is discharged as quicklime at the lower end into the cooling system. No more than 10 percent of the kiln is filled with limestone or lime as it moves slowly through the long cylindrical furnace in a gentle tumbling motion. Usually cooling air is induced into the discharge end of the product cooler and into the kiln as secondary combustion air. The combustion gases flow countercurrently to the flow of the stone to the charging end, where they are used to preheat the kiln feed. In the long rotary kiln, the exhuast gas temperature ranges between 593 and 760°C. In the external limestone preheater in the short rotary kiln, the exhaust gas temperatures range between 926 and 1148°C.

Rotary kilns can handle a range of stone feed sizes between 1/4 inch and 2 1/2 inches. When the feed size range is narrow and the minimum size is above 1/2 inch, a high degree of mixing in the bed during calcination produces a very uniform lime. A wide range of lime qualities can be produced from unreactive or dead-burned lime to highly active limes with $CaCO_3$ content between 0.2 and 0.8 percent.[6] Low sulfur lime, less than 0,035 percent sulfur, used by the steel industry can easily be produced in rotary kilns.

Cooling equipment used with rotary kilns is generally of two types, either satellite coolers for finer materials or contact-type coolers for coarse lime. Satellite coolers have less heat recovery but less maintenance and operating costs. Contact coolers have considerably more heat recovery but higher operating costs and appreciable head room requirements. Rotary coolers and grate type coolers are secondary choices in the lime industry.[7]

The major heat losses in a rotary kiln system are the heat in the lime discharged from the cooler, the radiation loss from the kiln itself, including the preheater, cooler, and other accessories, and the heat in the exit gas.[4] The heat that is used for calcination is transferred in three ways. The major heat transfer in a rotary kiln is by gas radiation from the hot flame and combustion gases. A much smaller amount of heat transfer results from brick radiation. The third and minor portion of heat transfer is due to convection when the hot gas stream comes in direct contact with the charge in the kiln.[4]

There is not much that can be done to increase radiation heat transfer, but heat transfer by convection can be greatly increased by additional mixing.[9] This mixing can be increased by dams, internal recuperators, trefoils and lifters. Some of the increased convection heat transfer is offset by slight reduction in the radiation heat transfer.[4]

The addition of internal mechanical mixing devices insures against horizontal stratification when the charge has a wide range of sizes. In long rotary kilns without internal mixing devices, the center of the charge in the kiln receives relatively little heat. This is because the fine particles insulate the charge from the brick lining and the larger particles roll over the top of the charge and receive most of the flame radiation.[9] Thus, a kidney-shaped core of unreacted limestone can be left in a medium-sized feed. This problem can be solved by installing internal mixers, reducing the loading to the kiln, or feeding a smaller size limestone.[4] If a kiln is to be run at full capacity with wide-sized feed, internal mixers must be added. However, the benefits of adding these devices will be offset to some extent by increased maintenance costs, higher dust loads in the exit gas, and larger amounts of fines in the product.

Fuel consumption of long rotary kilns generally averages 7.0 to 8.0 x 10^6 Btu per ton of lime produced while electric power consumption ranges from 24 to 32 kw hr per ton of lime produced. These calculations depend upon the type of firing and dust collection systems used. It should be added that heat transfer in rotary kilns is largely by radiation. Because long kilns have high surface radiation losses as well as exit gas losses, reducing the kiln length and replacing radiation heat transfer with direct gas contact and convection heat transfer results in lower exit gas temperatures as well as lower fuel consumptions. Efficient short kilns with preheater systems operate between 5.0 and 6.0 x 10^6 Btu per ton of lime; however, energy figures are somewhat higher than for long rotary kilns: 32 to 36 kw hr per ton of lime depending on the firing system used.[6] Space requirements for preheater systems are approximately 60 to 70 percent less than for long kilns. Preheater kiln systems are particularly efficient when equipped with contact-type coolers. The use of preheater systems is limited to feed materials which do not decrepitate or degrade during calcination.[6]

The capacity of the short rotary kiln is high, similar to that of the long rotary kiln, but the size will presumably remain smaller because of preheater designs.

Acceptable feed sizes for short kilns with preheaters are more limited than for long rotary kilns. Usually the minimum is 3/8 of an inch and the maximum is 1 3/4 inches. All available fuels and combinations can be used in a short kiln and the quality of the product is comparable to that of long rotary kiln limes. Mixing and bed motion in the calcination zone occurs to the same degree as in long rotary kilns but the material is exposed to the bed motion for a much shorter time. Feed is motionless on the grate-type preheaters and only in very slow and gentle motion in the shaft-type preheater. Therefore, material degradation and dust production is reduced in preheater systems.

Dust collection in preheater systems is further reduced by lower gas quantities being handled, which result from lower fuel consumption and lower exit gas temperatures. The preheaters also act as dust filters. This is particularly true of shaft type preheaters because of their generally higher bed.[6]

3.2.1.1.1 Model plant - A plant producing 500 tons of lime per day was chosen to be the model plant for the industry. Table 3-2 shows the characteristics of this plant. Defining a model plant is necessary in order to determine the various impacts of the control options discussed in Chapter 6. The expected growth in the lime industry is discussed in terms of the number of additional affected model plants per year. The effect the control options will have on the energy usage and emissions of the lime industry may be then quantified.

3.2.1.1.2 Other considerations - There can be significant sulfur dioxide (SO_2) emissions from rotary lime kilns. Sulfur is found in most limestone and in all fuels used in the industry except for natural gas. During fuel combustion and calcination, most of this sulfur is converted to SO_2. Some of the SO_2 will react with the lime product or with the lime dust and some will be emitted with the kiln off-gas as SO_2. The amount of SO_2 that reacts with the lime product or lime dust will depend on the chemical composition of the stone, the temperature in the kiln, the amount of excess oxygen in the kiln and the amount and particle size of the dust inside the kiln.[4]

The sulfur in the limestone feed does not normally contribute to a substantial portion of the total SO_2 emissions from a rotary kiln. Most of the limestone sulfur remains in the lime product. The major concern with respect to SO_2 emissions from rotary kilns is the sulfur content of the fuel. When natural gas is fired, there are negligible SO_2 emissions. When coal or oil with sulfur content less than 1.0 percent is used, up to 100 kilograms (220 pounds) of SO_2 may be produced but only about 10 percent of the sulfur in the fuel is vented to the atmosphere as SO_2. When high sulfur content coal is burned, a smaller percentage of the SO_2 is removed before the gases are exhausted

Table 3-2. UNCONTROLLED MODEL LIME PLANT[a]

Feed	1,000 tons stone/day
Product	500 tons lime/day
Heat required	6.5 x 10^6 Btu/ton lime
Yearly operation	330 days per year
Coal heat content	12,500 Btu/lb coal
Coal usage	130 tons coal/day
Electric Power usage	32 kw hr/ton lime
Dust load to cyclonic separator	7,100 pounds/hr
Dust load from cyclonic separator	2,130 pounds/hr
Potential SO_2 from coal	
1.0% coal	200 lb/hr
3.0% coal	650 lb/nr
NO_x emissions	60 lb/hr
CO emissions	20 lb/hr
Gas flow to control	48,000 SCFM (13.7% H_2O)
	41,000 DSCFM (8.2% O_2)
Gas flow to control device per ton lime	138,000 SCF (13.7% H_2O)
	119,000 DSCF (8.2% O_2)

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[a] Assumes "uncontrolled" plant to use cyclonic separators except for systems which use a baghouse.

[b] Assume an average dusting rate as percentage of lime produced of 17%.

and the SO_2 emissions can become significant. It is estimated that the uncontrolled emission of SO_2 would be as high as 38 kg/hr (84 lb/hr) for the model 500 tons of lime/day plant when it is using 3.5 percent sulfur coal (see EPA test data, Appendix C, Table C-2).

There are also carbon monoxide (CO) and nitrogen oxide (NO_x) emissions from rotary kilns. These emissions are shown for the model plant in Table 3-2. The presence of oxygen and CO in the exhaust is not theoretically possible but it occurs due to the incomplete mixing of the gases in the kiln. The concentration of CO in the off-gas can vary widely, from 15 to 580 parts per million in the EPA tests, depending mainly on the amount of excess oxygen in the kiln. Most lime kiln operators will try to keep both the oxygen and CO levels in the kiln off-gas below 0.5 percent during normal operations.[4] The formation of NO_x also depends upon the excess oxygen in the kiln, but it is the operating temperatures which determine the level of NO_x. Operating temperatures are normally fixed depending upon the type of product that is being made. NO_x emissions also vary widely, from 38 to 363 parts per million in the EPA tests. (See Appendix C.)

3.2.1.2 Other Kilns -

3.2.1.2.1 Vertical kiln - At one time, the vertical kiln, or shaft kiln, was the most widely used in the United States. Although may vertical kilns remain in operation in the U.S., the total capacity of the vertical kiln has fallen well behind that of the rotary kiln. This kiln design is basically an upright heavy steel cylinder lined with refractory material. Kiln dimensions may vary from about 3 to 8 meters in diameter and from about 11 to 31 meters in height with an average size of 3.7 by 16 meters.

In principle, most modern vertical kilns are divided into four largely imaginary zones that are often indistinguishable from each other. The proportioning and contouring of these zones constitute the "art" of vertical-kiln design. These zones from top to bottom are:

1. Storage. This is located at the top of the kiln and acts as a storage hopper or silo to receive the kiln feed.

2. Preheating. In this zone waste or recirculated exhaust gases preheat the stone preparatory to calcination in the zone below.

3. Calcining. This is the calcination chamber where at least 95 percent of lime burning occurs. The lower portion of this zone is often called the finishing zone where calcination is completed.

4. Cooling. Cool air enters this zone from the base of the kiln or discharge point and by natural or forced draft or by suction passes counter-current to the lime descending down the kiln. The air cools the lime but recoups much of the heat as secondary combustion air for the calcining zone above. The cooled lime is discharged onto conveyors below the kiln.

Many variations of the shaft-type kiln have been designed and are operating. Most of the more sophisticated and higher capacity kilns have been developed in Europe because of the appreciably higher fuel costs.

A primary advantage of vertical kilns over rotary kilns is the higher average fuel efficiency. The primary disadvantages of the vertical kiln are: (1) its relatively low production rate as compared to the rotary or rotary hearth kiln and (2) the inability to burn solid fuel (coal) without degradation in the quality of the lime. Of the fourteen known lime kiln installations built in the U.S. since 1969, none were vertical kilns.[8]

3.2.1.2.2 Rotary hearth kiln - The rotary hearth kiln, or Calcimatic kiln, is a circular-shaped kiln with a slowly revolving donut-shaped hearth. The circular refractory hearth is supported on two concentric tiers of rollers that can be operated at various speeds of 35-200 min/revolution. The remainder of the kiln is stationary. The hearth is divided into zones, and through instrumentation precise temperatures can be maintained at these different zones. Heat is supplied by multiple natural gas or oil burners, and the limestone is fed from a preheater chamber onto the hearth.

The hearth will accomodate a rather wide range of stone sizes, including relatively broad graduations, such as 1/4 to 4 inches. The stone is distributed in an even bed of one-to-six inch depth.

The finished lime is scraped off about 350° around the circle from the point where the feed limestone is spread onto the hearth. The heated gases from the calcination zone of the kiln are passed through the feed limestone for preheat purposes, similar to the procedure in the vertical kiln. In some cases, the cooling of the lime product is done in an indirect heat exchanger where the burner combustion air is preheated, thus adding to the fuel economy.

The rotary hearth kiln combines the advantages of the rotary kiln and the vertical kiln in that a high production rate can be achieved with low dust emissions. Here again, however, the kiln cannot be operated with solid fuel.

3.2.1.2.3 Fluidized bed kiln - Fluidized bed kiln systems have found limited application in the lime industry because of their narrow feed size requirements. This patented kiln utilizes a very fine particulate kiln feed of No. 8 to No. 65 mesh that is fluidized or air-floated by controlled air and combustion gases as it descends through preheating and calcining zones. The finely divided limestone is brought into direct contact with hot combustion air in a turbulent zone, usually above a perforated grate. The stone is physically tossed and bounced about by the turbulent air and quantities of dust are carried out of the reaction zone by the combustion air.

3.2.1.2.4 Kiln emissions comparison - A comparison of the four types of kilns in terms of uncontrolled particulate emissions reveals the fluidized bed kiln to have the highest uncontrolled dust output. This is due primarily to the very small feed size combined with the high air flow through the kiln. The long rotary kiln is second to the fluidized bed kiln in uncontrolled particulate emissions. This is attributed to the small feed size and dusting caused by rolling of the feed through the kiln. Short rotary kiln with external preheater and the rotary hearth or "Calcimatic" kiln rank third in dust production, primarily because of their larger feed size combined with the fact that the limestone remains in a stationary position during calcining. The vertical kiln has the lowest dust emission during operation. This is attributed to the large lump-sized feed and the slow movement of the feed material through the kiln.[8]

3.2.2 Hydration and Its Emissions

Although most lime produced is sold as lime, a small amount (10 percent in 1974) is converted into slaked lime or hydrated lime. The reaction can be shown as follows:

$$CaO + H_2O \rightarrow Ca(OH)_2$$

In most hydration plants water is added to the lime in a pug mill premixer where there is thorough blending of the lime and water. The lime-water mix then goes to the agitated hydrator where most of the chemical reaction takes place. The reaction is exothermic and the heat of reaction converts part of the water in the mix to steam. A fan maintains a slight negative pressure in the hydrator and the steam is discharged to the atmosphere along with any air that enters the hydrator through the charging port. Hydrator emissions are normally controlled by the use of either water sprays in the hydrator stack or by wet scrubbers. The resulting slurry or milk of lime is usually returned to the premixer as part of the slaking water. Virtually all hydrators have this equipment integrally installed.[2] Occasionally a rate retardent is added to the mixture in order to control the heat of the reaction. The amount of water added is critical. If too much water is added, it will be impossible, or require costly drying, to produce the desired dry form. If too little water is added, incomplete hydration will cause a lowering of product quality. If the hydration is done properly, the resulting product should be in the form of a fluffy, micron-sized, dry, white powder.

A plant that hydrates 14 tons of lime per hour and produces 17 tons per hour of hydrate was chosen to be typical for the hydrate process. Table 3-3 presents a listing of the characteristics of this plant, which is used as a base for assessing the impacts due to each control option discussed in Chapter 6.

Table 3-3. TYPICAL LIME HYDRATE PLANT

Feed	14 tons of lime per hour
Yearly operation	4700 hours per year
Product	17 tons of hydrate per hour
Gas flow to scrubber	6,000 ACFM (85% H_2O + 175°F) 700 DSCFM
Gas flow from scrubber	10,000 ACFM (47% H_2O + 175°F) 4,400 DSCFM
Dust load to scrubber	1,200 pounds/hr

3.2.3 Fugitive Emissions

The uncontrolled fugitive particualte matter emitted from transfer points, screens, and loading operations in lime plants have not been qualified, and are thought to vary widely depending on individual plant practice. In an old plant there can be as many as 30 of these miscellaneous sources. A new, well designed plant would probably have fewer than 15. The amount of particulate in the uncontrolled emissions is estimated at about 5 pounds per ton of lime.[1] Based on this estimate, fugitive emissions may account for as much as 10 percent of the total particulate emissions at typical lime plants.

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CHAPTER 4. EMISSION CONTROL TECHNOLOGY

The various devices that are used to control emissions from the calcination and hydration processes at lime manufacturing plants are described in this chapter. The presentation discusses the types of devices presently in service in the industry, and the levels of emission reduction attainable by each. The levels of emission reduction are derived from EPA tests, other tests performed by state and local agencies, industry tests, and vendor guarantees.

4.1 CALCINATION EMISSION CONTROL TECHNOLOGY

Four types of emission control are used to control particulate matter from rotary lime kilns. These devices are:

1. Baghouse
2. Electrostatic Precipitator (ESP)
3. Venturi scrubber
4. Gravel Bed Filter

All of these control devices can be designed to attain very high collection efficiencies. There are advantages and disadvantages associated with the use of each device.

The rotary kiln off-gas to these devices is the same as the one described in Chapter 3. Table 3-2 gives the parameters of this off-gas stream for the model plant.

4.1.1 Baghouse

When baghouses are used for controlling dust emissions from rotary kilns, tubetype, glass fiber bags with graphite and silicone finishes are specified. Some form of gas cooling is required since these bags cannot withstand temperatures above 288°C (550°F) and the kiln exhaust temperature is generally in excess of 538°C (1000°F). This cooling can be achieved by (1) evaporative water sprays, (2) indirect radiation convection heat exchange, (3) ambient air dilution, (4) external stone preheater, or (5) a combination of these. The fabric filter bags are typically 5 to 12 inches in diameter, 10 to 30 feet long, and weigh 14 to 18 oz. per square yard. Generally a baghouse has from 4 to 12 individual compartments containing 200 to 600 bags each.

The bags are used as a filter media to remove the dust from the gas stream. As the dust-laden gas is forced through the fabric, the dust collects on the fabric, forming a cake which also helps in the filtration. Fabric filter effectiveness is primarily a function of kiln exhaust particle size distribution, fabric type, fabric age, and maintenance history. Pressure drops of around 5 inches water column (IWC) are typical for fabric filters used in the lime industry. At some preset time interval, one of the compartments is taken off line and a reverse gas flow is forced through the fabric, releasing the cake. The cake of dust falls into a hopper where it is sent by pneumatic or screw conveyor to eventual disposal.

When one compartment is off-line for cleaning, the total available filtration area is reduced. Therefore, filter units are designed on the basis of air-to-cloth ratios (cubic feet per minute of air per square foot of cloth) for the total unit with one compartment off-line for cleaning. Air-to-cloth ratios for lime kiln exhaust are nominally 2.2/1 when one compartment is off-line.[1]

Properly designed and operated baghouses will have a bag life of from 22 to 34 months.[2]

Baghouses have the primary advantage of offering the highest average particulate collection efficiency for lime kiln exhaust gas treatment. They are also tolerant of process upsets that lead to short-term heavy loadings. The dry waste dust can potentially be used for a variety of purposes as described in Chapter 6. The main disadvantages of the fabric filter collector are (1) large physical size space requirement, (2) high capital cost, and (3) high maintenance cost.

Of the lime plants tested by the EPA, the plants controlled by baghouses averaged the lowest particulate emission rates. (See Appendix C, Table C-1.) In tests performed at two separate lime plants, the average emissions were 0.041 and 0.111 kilogram of particulate per megagram of feed (0.082 and 0.222 lb/ton). The particulate concentrations for the two plants were 0.01 and 0.05 grams per dry standard cubic meter. At the low concentrations found in the EPA tests, there are normally no visible emissions; the only visible emissions recorded were those seen for a few seconds when a compartment went back on line after cleaning. The visible emission readings taken during the particulate testing are also summarized in Appendix C. The maximum six-minute average opacity that was observed during the particulate testing normalized to a 3.0 meter stack diameter was 7.0 percent; over 95 percent of the six-minute averages were zero and all of the readings were less than 10 percent. In a non-EPA test of three other baghouses, an average emission of 0.13 kilogram of particulate per megagram of limestone feed (0.27 lb/t) was found.[3]

The SO_2 emissions from rotary lime kilns controlled by baghouses are shown in Figure 4-2 and in Appendix C. These data indicate a wide range of SO_2 removal efficiencies, which ranged from 82 to 93 percent removal. There appears to be a relationship between the SO_2 removal efficiency and the percent sulfur in the coal.

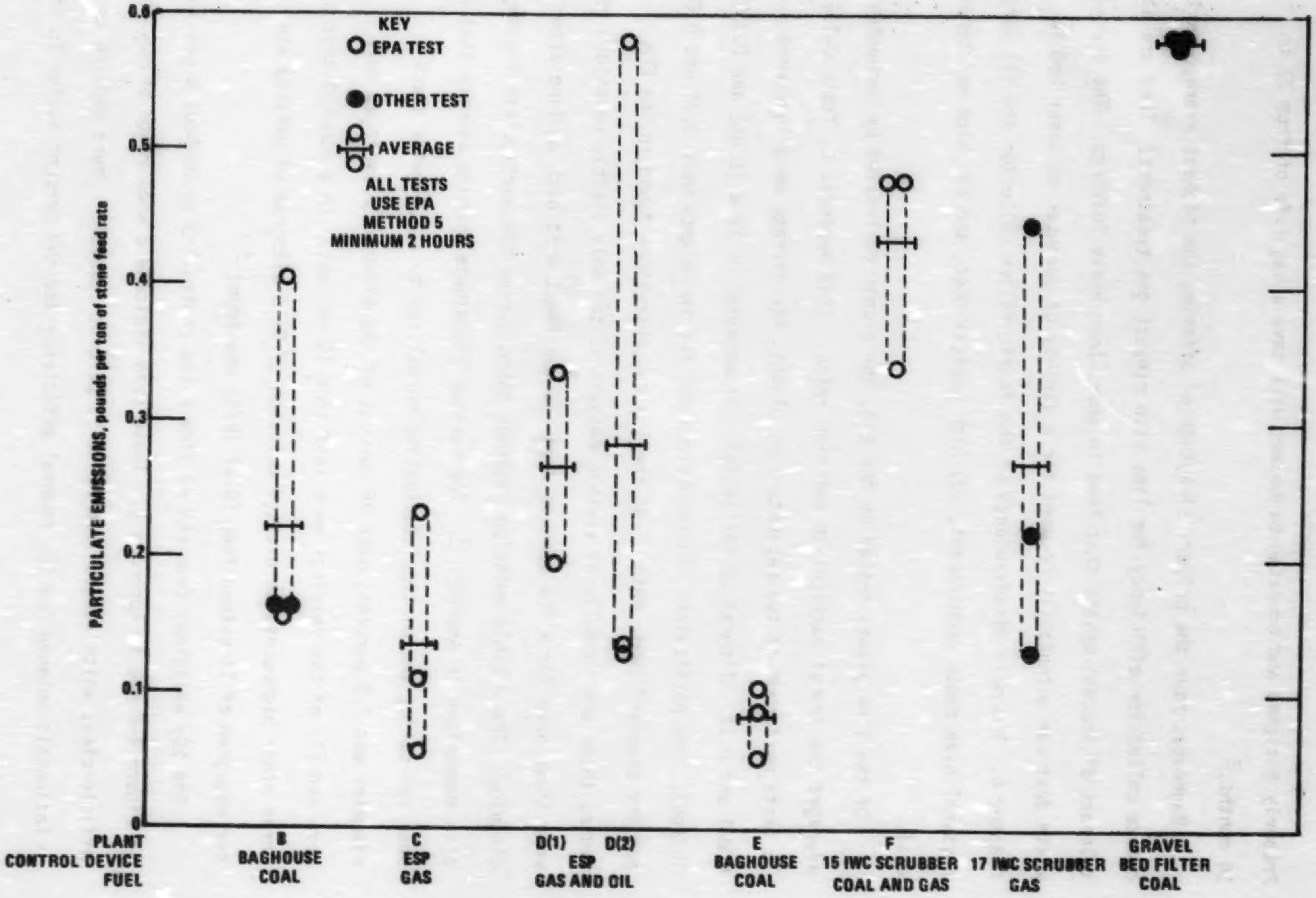

Figure 4-1. Particulate Emissions from Rotary Lime Kiln Facilities.

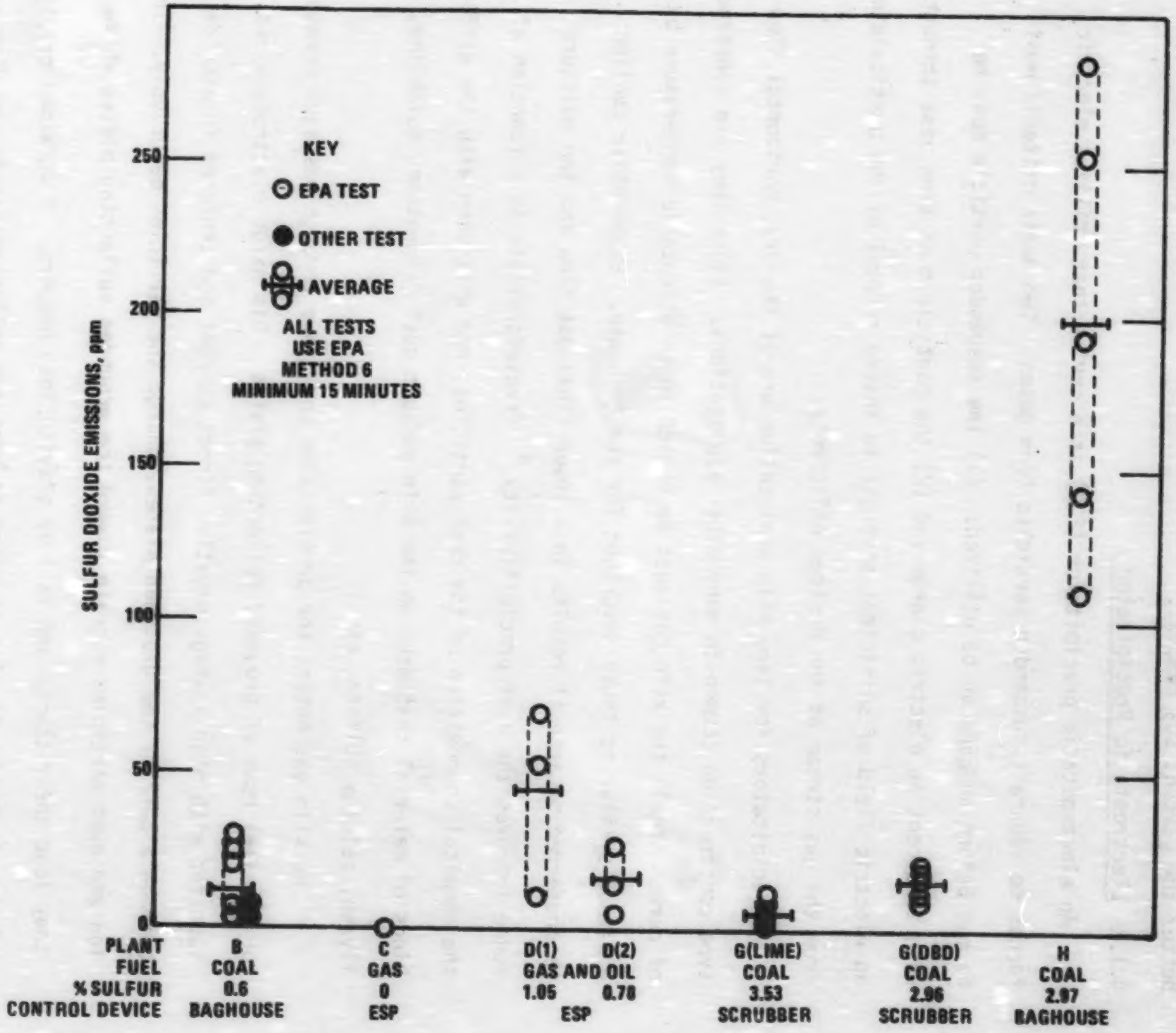

Figure 4-2. Sulfur Dioxide Emissions from Rotary Lime Kiln Facilities.

Generally the less sulfur there is in the fuel used to fire the kiln, the better the percent SO_2 removal.

4.1.2 Electrostatic Precipitator

An electrostatic precipitator (ESP) is a device that utilizes electric forces to separate suspended particles from gases. Two basic criteria must be met before an ESP can be utilized: (1) the suspended particle must be able to accept an electric charge and (2) the particle must then pass through an electric field of sufficient strength to insure removal of the particulate from the gas stream at the desired efficiency.

Precipitators for lime kiln application are of the dry, horizontal flow type construction common to many other applications. Since they are constructed of carbon steel, the kiln gas must be cooled to an acceptable temperature by a method similar to those described for the baghouse. Evaporative cooling is preferred because it results in a lower final gas flow and the moisture added improves the dust precipitability.[4] Precipitability is a function of the chemical composition of the dust particles, and will vary with the different kinds of material that make up the kiln exhaust dust (limestone, quicklime, flyash, calcium sulfate, etc.).

The kiln gas enters the precipitator and flows through passages created by parallel rows of grounded collecting plates. Discharge electrode wires, supplied with high voltage negative direct current and centered in each passage between a pair of the grounded plates, charge the particles negatively. The ionized dust particles migrate toward the grounded collecting plates where they lose their charge and fall by gravity into hoppers. Programmed rapping of the electrodes is also required to keep the collector plates and discharge electrodes clean.

For an ESP to function optimally, the gas should be evenly distributed across the collectors. These plates should have the maximum voltage and power possible without sparking. The two main factors influencing the efficiency of a precipitator are the gas velocity and treatment time. Thus, higher efficiencies are attained in any process by increasing the precipitator size. Although virtually any desired efficiency can be obtained, normally precipitators operate in the range of 90 to 99 percent particulate removal.[1]

The primary advantages of the electrostatic precipitator are apparent in the cases where "dry" collector systems are required. In these instances, electrostatic precipitators require amounts of space similar to that required by a baghouse, although the operating costs are found to be lower. The resulting waste is a dry dust which may be disposed of in a variety of ways as described in Chapter 6. The major disadvantages of this collector are its high capital cost and its relatively low collecting efficiency on submicron particles. A high level of maintenance skill is needed to keep an ESP in operation at design conditions. In addition, a potential fire hazard exists during start-up periods if flammable dusts or fuels accumulate in the discharge zone of the precipitator.

The results of EPA particulate emission testing at two lime plants utilizing electrostatic precipitators are presented in Figure 4-1. The particulate emissions in three tests of these two plants ranged from 0.015 to 0.082 g/dscm (0.0068 to 0.036 gr/dscf). The emissions from plant C averaged 0.068 kg/Mg of stone feed (0.135 lb/ton). The emissions from plant D averaged 0.133 and 0.141 kg/Mg of stone feed (0.266 and 0.282 lb/ton) in two separate emission tests. Neither of the plants tested by EPA used coal for fuel; one burned natural gas and the other operated on a mixture of oil and natural gas. A third plant, not tested by EPA, that operates on coal and 20-30 percent natural gas also has 99-plus percent collection efficiency.

This plant uses an atomized water spray to cool the kiln gases and to assist the dust precipitability. The dust-laden gases then enter a three-chamber ESP where the dust is removed.[5]

There are more visible emissions from an ESP than a baghouse, but an ESP should be capable of achieving below 10 percent opacity if it is operating normally. During the EPA particulate source tests, visible emission readings were taken which are summarized in Appendix C. The maximum normalized 6-minute average opacity observed during the tests was 10.1 percent. Over 56 percent of the 6-minute averages were zero, and over 99 percent of the averages were less than 10.

The SO_2 emissions from a rotary lime kiln controlled by an electrostatic precipitator are shown in Figure C-2. Since one of the kilns tested was burning natural gas during the test, no SO_2 was found in the exhaust stream from the ESP. The second kiln was burning a mixture of natural gas and oil. Only 12 percent of the sulfur in the fuel oil was found in the exit gas from the ESP.

4.1.3 Wet Scrubbers

The most common high pressure drop scrubber used for controlling emissions from rotary lime kilns is the venturi scrubber. This scrubber consists of two tapered sections which form a throat in the air passage. The contaminated gas stream is accelerated through the venturi-shaped throat section, reaching velocities of 150 to 400 feet per second.[6] Water is introduced just ahead of the venturi throat by means of an overflow or through nozzles or slots, and is atomized into fine droplets by the action of the high velocity gas stream. The dust particles in the gas stream collide with and are captured by the small liquid droplets. Downstream of the venturi, the droplets coalesce so that some comparatively simple form of water-gas separation device, such as a cyclone separator, may be used for collection.[7] Gas-water contact in the venturi is so thorough that even the submicron particles are removed. The efficiency of particulate removal is a direct function of the energy input, measured by the pressure drop across the venturi throat. Throat pressure drop can range from 8 to 40 inches of water column (IWC), depending upon the particle size and the degree of cleaning required. For high removal efficiency of particulate matter in emissions from rotary kilns, it is estimated that a pressure drop of about 22 IWC is necessary. This number was derived from extrapolation of known data and expert opinion.

The primary advantages of the venturi scrubber are its small space requirement and its low capital cost. However, the venturi scrubber also has several disadvantages. Although low pressure drop scrubbers use less energy than high pressure drop scrubbers, even a low efficiency scrubber with a 9 IWC pressure drop requires more energy than any of the other high efficiency control devices discussed in this chapter. Scrubbers require ponds for separation of the collected particulate from the scrubbing water, which is then reused. These ponds must be located so that they do not receive excessive rainwater run-off, which could cause overflow into local navigable waters. Such an overflow is prohibited by Federal regulation unless it occurs as a result of a 25-year rainfall occurring over a 24-hour period. In such a case only an amount of water equal to the rainfall excess can be legally discharged.[8] Some plants would not have suitable land area available for these settling ponds, in which case the plants could use slurry settling tanks to dewater the slurry product requiring minimal land area for water treatment and solids disposal.[9]

There are few high pressure drop scrubbers (22 IWC) in use on U.S. rotary lime kilns. In a non-EPA test of a lime kiln operating at 100 percent of capacity, particulate emissions averaged 0.134 kg/Mg of stone (0.267 lb/ton). The scrubber used to control emissions from this kiln was designed for 22 IWC but was operating at only 17 IWC during testing.[10] The results of EPA particulate emission tests on one kiln scrubber operating at 15 IWC are shown in Figure 4-1. The emissions ranged from 0.048 to 0.72 g/dscm (0.021 to 0.32 gr/dscf) and averaged 0.062 g/dscm (0.0274 gr/dscf). The average process weight emission rate was 0.216 kg of particulate per megagram of limestone feed (0.431 lb/ton). Few visible emission readings were taken during the particulate tests on this kiln because the large steam plume made all possible readings suspect. There did appear to be some visible emissions, but they could not be quantified.

In two other tests, one on the same scrubber at a lower (11-12 IWC) pressure drop[11] and another on a similar scrubber with a 15 IWC pressure drop,[12] average process weight particulate emission rates of 0.232 and 0.163 kg/Mg of stone feed (0.463 and 0.326 lb/ton), respectively, were found.

Venturi scrubbers give excellent control of SO_2 emissions when applied to lime kilns. EPA tests on three separate kilns show efficiencies of SO_2 removal in excess of 98 percent. (See Appendix C, Table C-2.) On a rotary kiln burning 1.86 percent sulfur coal, the inlet SO_2 concentration averaged 162 ppm while the outlet concentration was near zero (Dynascience continuous monitor used). On a lime kiln burning high sulfur coal (3.53 percent sulfur), the inlet loading was 265 kg/hr (585 lb/hr) of SO_2 while the outlet was 1.3 kg/hr (2.9 lb/hr), a reduction in excess of 99 percent. On a dead-burned dolomite kiln burning high sulfur coal (2.96 percent sulfur), the emission reduction due to the scrubber was measured as 160 to 3.5 kg/hr (350 to 7.8 lb/hr), a reduction of about 98 percent.

Lime slurry scrubbers can also be used in series following baghouses or ESP's to control the SO_2 emissions from rotary lime kilns. These scrubbers have different designs than scrubbers designed for particulate control. The pressure drop required would be less and the residence time would be greater. Although no combination device of this sort is now in operation on any U.S. lime kiln, it is not uncommon in the utility industry. It is estimated that such a combination would give SO_2 and particulate control with less energy use than a high energy (22 IWC) scrubber alone. The combination device would, however, have a capital cost almost double that of a single device used alone.

4.1.4 Gravel Bed Filter

Gravel bed filters have only recently been applied to U.S. rotary lime kiln emissions although they have been widely used in Europe. Gravel bed filters clean exhaust gases in three steps. First the gas enters the filter and loses velocity so the large chips can settle out. The medium sized particles are removed by cyclonic separation. Finally the smallest particles are removed by agglomeration as they pass through a filter medium of crushed stone. The cleaned gas is then vented to the atmosphere. Usually six to fourteen filters are used in parallel. In some cases each of these filters is placed in series with a second filter for greater economy and space saving.[13]

Accumulated dust is removed by isolating one of the gravel beds and reversing the air flow through it. After a short time lag the gravel bed is raked by a mechanical stirring device. The dust laden cleaning air then goes to a cyclone and a settling chamber where its velocity is reduced and most of the dust settles out. The cleaning air is then sent to the other gravel beds for filtering. The cleaned gravel bed is then put back on line and another filter is cleaned.[14]

There are several advantages to using the gravel bed filter for lime kiln off-gas. There is no need to change or repair the filter media, no need for water, and the maintenance costs are small with little down time. The waste dust is dry and saleable assuming a market can be established. The major disadvantage associated with the gravel bed filter is the high operation costs due to the pressure drop which can be as high as 10 IWC.[11]

No EPA tests were performed on gravel bed filters. Seven source tests on a plant using 8 gravel bed filters showed a particulate process weight emission rate that ranged from 0.243 to 0.5 kg/Mg of stone feed (0.487 to 1.00 lb/ton).[14] In a second source test on a plant using 20 gravel bed filters to control a 725 megagram (800 tons) of lime per day preheater kiln, an average particulate process weight emission of 0.14 kg/Mg of limestone feed (0.28 lb/ton) was found. In this test there was also a 93 percent removal of SO_2 through the system with an average emission of 17 parts per million of SO_2.[11]

4.2 HYDRATION EMISSION CONTROL TECHNOLOGY

As stated in Chapter 3, uncontrolled hydration emissions consist of particles of hydrated lime in a very moist 99°C (210°F) gas stream. There are no gaseous pollutants present. Hydration emissions have been shown to be most effectively controlled by wet scrubbers, but a baghouse has been used in at least one case. In order to use a baghouse, however, the exhaust gas must be superheated in order to avoid condensation of the near saturated gas stream. Therefore, wet scrubbers are the only system of emission reduction considered for this facility.

The most common type of scrubber used on lime hydrators is the wetted fan type with centrifugal separation. Water is sprayed into the center of the draft fan and is thus forced to mix with the gas stream. More water is

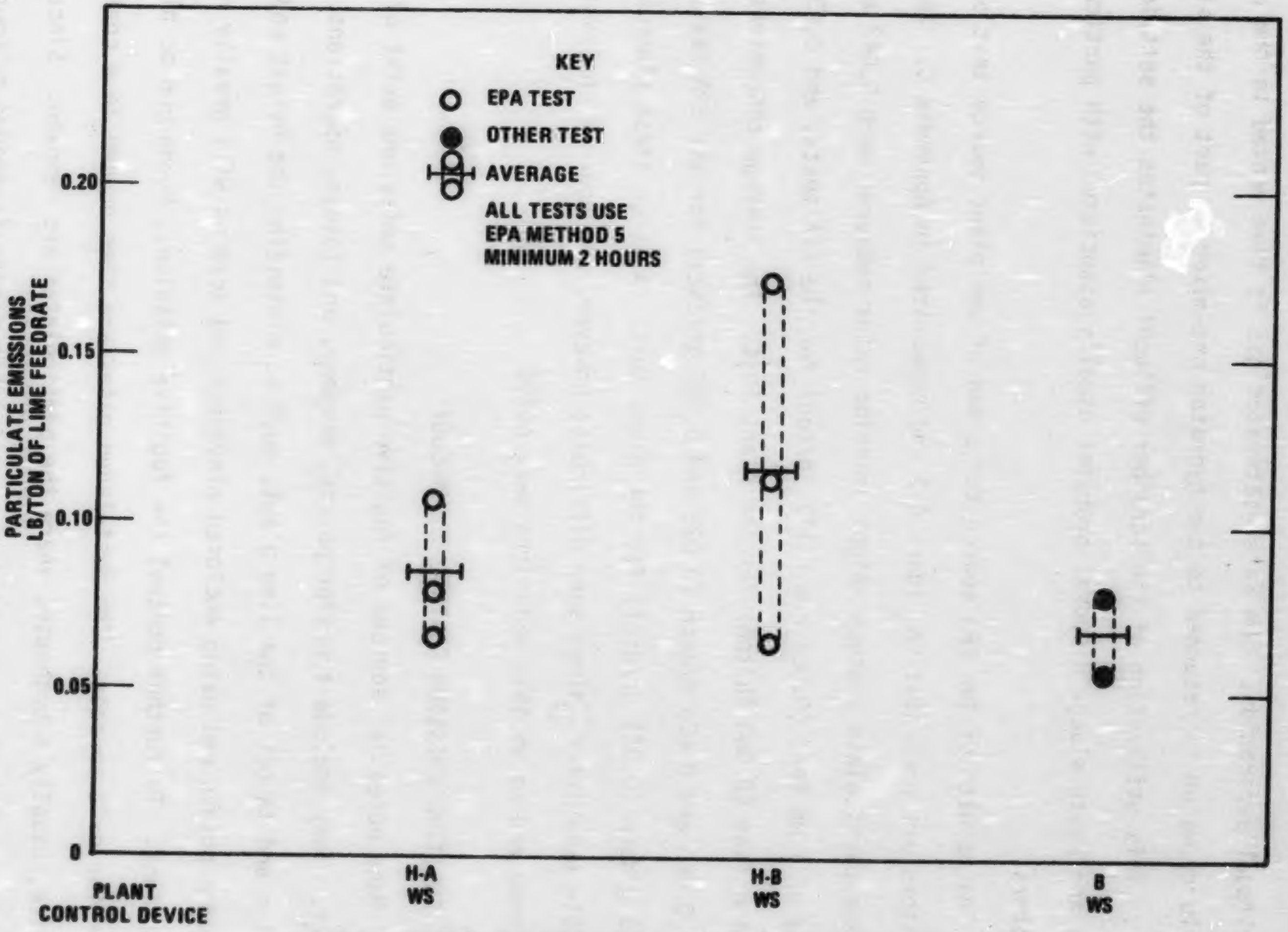

Figure 4-3. Particulate emissions from lime hydration facilities.

sprayed into the duct carrying this gas-water mixture just after the fan. The dust-laden slurry water is then removed from the cleaned gas stream by centrifugal separation. The water-saturated gas is then vented to the atmosphere. The slurry water is returned to the hydrator pre-mixer as part of the slaking water. This utilization of the scrubber effluent eliminates the settling ponds and waste sludge disposal problems usually associated with particulate scrubbers.

The results of two EPA source tests and of one plant source test on lime hydrators are presented in Figure 4-3 and summarized in Appendix C. The average particulate process weight emission rates measured were 0.042 and 0.059 kg/Mg of lime feed (0.084 and 0.117 lb/ton) for the EPA tests, and 0.034 kg/Mg of lime feed (0.068 lb/ton) for the plant test. The average concentrations were 0.066 and 0.423 g/dscm (0.029 and 0.186 gr/dscf) for the EPA tests and 0.055 g/dscm (0.024 gr/dscf) for the plant test. A large steam plume made visible emission readings very difficult; however, one hour of observation was made and no visible emissions were noted.

4.3 FUGITIVE EMISSION CONTROL TECHNOLOGY

Many potential sources of fugitive particulate emissions exist at a lime plant. They include transfer points, screens, and loading operations. Proper design and layout of the lime plant, such as minimizing the height and number of drop points and using enclosed elevators and screens will greatly reduce emissions. To further control the fugitive emissions, hoods can be placed over the exit sources. The dust-laden gases are then ducted to a control device, usually a baghouse, where the particulates are removed. Since the gas is at ambient temperature, no special bag fabric is needed although polypropylene appears to be best suited for this application. The dust from the product handling operations can then be briquetted and returned to the system or sold as dust for water treatment.[15]

With adequate pickup velocity through a hood visible emissions from a fugitive emission point should be very low. If the elevators and screens are enclosed and vented to a control device they should also have very low visible emissions. Little data or information is available, however, which identifies to what extent the use of hoods or various other types of enclosures would reduce visible emissions. Consequently, the performance of these emission control techniques cannot be quantified.

4.4 STATE REGULATIONS

In most States, new lime plants are subject to (1) general process weight regulations designed to limit particulate emissions from any source and (2) regulations designed to limit SO_2 emissions from all fuel-burning sources and based on the Btu content of the fuel combusted expressed in millions of Btu's per hour. For the 907 megagram (1000 ton) per day limestone feed model kiln, the average State regulation will allow 0.5 kilogram of particulate matter per megagram of stone feed (1.0 lb/t) and 3.1 kilograms of SO_2 emissions per megagram of limestone feed (6.2 lb/t).[16] The average State regulation for control of emissions from the typical hydrator is 0.5 kilogram of particulate per megagram of lime feed (1.0 lb/t).[17]

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5. MODIFICATION AND RECONSTRUCTION OF ROTARY LIME KILNS AND LIME HYDRATORS

The proposed standards apply to all affected facilities constructed or modified after the date of proposal of the proposed standards. Provisions applying to modification and reconstruction were originally published in the Federal Register on December 23, 1971. Clarifying amendments were proposed in the Federal Register on October 15, 1974 (39 FR 36946), and final regulations were promulgated in the Federal Register on December 16, 1975 (40 FR 58416).

Modification is defined as "any physical change in, or change in the method of operation of, any existing facility which increases the amount of any air pollutant (to which a standard applies) emitted into the atmosphere by that facility or which results in the emission of any air pollutant (to which a standard applies) into the atmosphere not previously emitted." Reconstruction occurs when components of an existing facility are replaced to such an extent that:

(1) The fixed capital cost of the new component exceeds 50 percent of the fixed capital cost that would be required to construct a comparable entirely new facility, and

(2) It is technologically and economically feasible to meet the applicable standards.

In the case of reconstruction, the reconstructed facility is covered by the standard whether or not an increase in emission occurs.

There are certain circumstances under which an increase in emissions does not result in a modification. If a capital expenditure, that is less than the most recent annual asset guideline repair allowable published by the Internal Revenue Service (Publication 534), is made to increase capacity at an existing facility and also results in an increase in emissions to the atmosphere of a regulated pollutant, a modification is not considered to have occurred. However, all potential modifications have to be reported even if it can be proven that there was no increase in emissions to the atmosphere. Other cases under which an increase in emissions does not constitute a modification occur when the increase is caused by an increase in capacity throughput or a change in the type of fuel being used when these changes do not involve a change in the original design of the facility. Additionally, if an increase in emissions has occurred which could be considered a modification, the amount of increased emissions, in kg per hour, may be traded off by reducing emissions of the same pollutant from another facility within the same plant as long as it can be shown that the total emissions of that pollutant from the plant has not increased. This is referred to as the "bubble concept".

The purpose of this chapter is to identify some of the potential modifications and reconstructions of affected facilities, and any exemptions or special allowances covering changes in existing facilities that should be considered. Exemptions from the regulations may be based on availability of technology and economic considerations;

The following physical and operational changes of rotary lime kilns were considered:

(1) Conversion from natural gas or fuel oil to coal firing;

(2) Adding a limestone preheater to an existing kiln;

(3) Adding internal baffling to an existing kiln to increase mixing;

(4) Expanding the capacity of the production limiting component of the facility (debottlenecking).

There are no anticipated modifications for lime hydrators. If, however, a process modification does occur that would potentially increase emissions to the atmosphere, the increase in emissions could be controlled by either increasing the pressure drop across the water scrubber or by adding additional scrubbing water and maintaining the same pressure drop across the water scrubber.

5.1 CONVERSION FROM NATURAL GAS OR FUEL OIL TO COAL FIRING

An existing rotary lime kiln that burns natural gas or fuel oil may be converted to burn coal. If the kiln was not originally designed to burn the alternative fuel, the conversion will constitute a modification if there is an increase in emissions to the atmosphere. Fuel conversion would cause an increase in particulate emissions from the kiln and therefore is a potential modification. Whether or not there would be any increase in emissions to the atmosphere would depend on the type of control device used. A baghouse has proven to be rather insensitive to small changes in the inlet loading. In tests conducted at the Ideal Company Devil's Slide Cement Plant on a baghouse controlling a rotary cement kiln, there was no increase in emissions when the kiln was converted from fuel oil to coal firing. The effect of fuel conversion on collection efficiency when an ESP is used to control particulate emissions is not known. If there was an increase in emissions from a scrubber following fuel conversion, either increasing the pressure drop or the amount of scrubbing water will reduce the particulate emissions to the atmosphere to the pre-conversion level.

5.2 ADDING A STONE PREHEATER TO AN EXISTING KILN

An existing rotary lime kiln may retrofit a stone preheater in order to cool the exhaust gases before they enter the control device. The addition of a preheater will also reduce the energy consumption per ton of lime and increase the production rate. The stone bed in the preheater will act as a dust precleaner so that there will be no increase in dust loading to the control device. Even though the production increases, the air flow to the control device will not increase because of the lowered fuel consumption. Therefore, it appears that when a stone preheater is added to an existing kiln there will be no increase in particulate emissions from the control device to the atmosphere.

5.3 ADDING INTERNALS TO AN EXISTING KILN

The addition of internal baffling to an existing kiln is another way to reduce the energy consumption per ton of lime. Dams, internal heat recuperators, trefoils and lifters are used to increase mixing of the kiln charge so that the heat will be more readily transferred to the stone. This increase in mixing will also result in an increase in particulate emissions from the kiln. As in Section 5.1, the effect this will have on emissions is dependent upon the type of control device in service.

5.4 DEBOTTLENECKING

Expanding the capacity of the production limiting component of the facility (debottlenecking) will increase the production of the facility. Such alterations will have to be evaluated on a case by case basis to determine if the increase in capacity resulted from a "capital expenditure" as described in IRS Publication 534 and if there will be an increase in emissions to the atmosphere. Normally the changes will be made to modernize the equipment and will not result in substantial increases in production. Therefore, there will likely be a small (if any) increase in particulate emissions from the kiln and, again depending upon the type of control device in operation, potentially no increase in emissions to the atmosphere.

6.0 ENVIRONMENTAL IMPACT

The air pollution impact and the other environmental consequences of the alternative systems of emission reduction presented in section 6.1.1 are discussed in this chapter. The emission sources for which these alternative systems are considered are the rotary lime kiln off-gas and the lime hydrator off-gas. A comparison will be made between the emissions from the systems required to meet State regulations for these two sources and the emissions from other demonstrated systems. Both beneficial and adverse impacts which may be directly or indirectly attributed to the operation of these alternative systems will be assessed.

6.1 IMPACTS OF CONTROL TECHNOLOGY FOR ROTARY LIME KILNS

In Chapter 4 four different types of particulate emission control devices for rotary lime kiln off-gas are discussed. Three of these devices, the baghouse, electrostatic precipitator, and the venturi water scrubber, can be designed to reduce the emission levels from lime kiln off-gas to 0.15 kilograms of particulate per megagram of limestone feed (0.3 pounds/ton).

Emissions of SO_2 in rotary kiln off-gas are also controlled to some extent by these particulate control devices. Data from three tests show that a medium pressure drop water scrubber can reduce the SO_2 exit gas concentration from a kiln burning high sulfur coal to less than 100 ppm. Data from an EPA test show that kilns burning high sulfur coal and equipped with baghouses have SO_2 exit gas concentrations of 200 ppm.

6.1.1 Alternative Emission Control Systems

In this chapter four alternative emission control systems for rotary lime kilns are presented. Two systems (B-1 and B-2) control SO_2 to 100 ppm and two (A-1 and A-2) have no SO_2 control. Two systems (A-1 and B-1) control particulate emissions to 0.15 kg/Mg of limestone feed (0.30 lb/ton) and two (A-2 and B-2) control particulate emissions to 0.30 kg/Mg of limestone feed (0.50 lb/ton). These four systems are shown in Table 6-1. A fifth system (C), that of no additional control, will also be presented. Under this system owners or operators would be required to meet the typical State regulation, described in section 4.4. Table 6-2 shows the conversion of the concentration emission factors for particulate and SO_2 into other equivalent emission factors. The conversions are exact for the model kiln described in chapter 3 and will vary slightly from kiln to kiln depending primarily on the kiln fuel efficiency and the fuel used.

Table 6-1. ALTERNATIVE EMISSION CONTROL SYSTEMS FOR ROTARY LIME KILNS

Particulate Control Levels	SO_2 Control Levels	
	No SO_2 Control	100 ppm
0.15 kg/Mg (0.30 lb/ton)	A-1	B-1
0.25 kg/Mg (0.50 lb/ton)	A-2	B-2
0.50 kg/Mg (1.00 lb/ton)	C	-

The control equipment required for each of the five alternative emission control systems is described in the following section. An estimate is made of the percentage of industry capacity that will be controlled by each of the available devices so that the total energy required for emission control by the industry can be calculated.

Table 6-2. CONVERSION FACTORS FOR MODEL KILN AND MODEL HYDRATOR[1]

Kiln							
Particulate							
kg/hr	lb/hr	kg/Mg stone	lb/ton stone	kg/Mg lime	lb/ton lime	gr/SCF[2]	gr/DSCF
5.7	12.5	0.15	0.30	0.30	0.60	0.030	0.035
9.4	21	0.25	0.50	0.50	1.00	0.051	0.059
19	42	0.50	1.00	1.00	2.00	0.102	0.118
SO_2							
kg/hr	lb/hr	kg/Mg stone	lb/ton stone	kg/Mg lime	lb/ton lime	ppm (dry)	lb $SO_2/10^6$ Btu
1.9	4.2	0.05	0.1	0.1	0.2	10	0.03
19	42	0.50	1.0	1.0	2.0	100	0.3
38	84	1.00	2.0	2.0	4.0	200	0.6
120	260	3.10	6.2	6.2	12.04	620	1.8
Hydrator							
Particulate							
kg/hr	lb/hr	kg/Mg lime	lb/ton lime	kg/Mg hydrate	lb/ton hydrate		
0.96	2.1	0.075	0.15	0.06	0.12		
6.4	14	0.50	1.00	0.40	0.80		

[1] Model kiln and hydrator are described in Chapter 3. Kiln produces 500 tons lime a day from 1000 tons stone and 6.5 x 10^6 million Btu per ton lime. Hydrator produces 17 tons of hydrate per hour from 14 tons lime.

[2] At 70°F wet.

Control System A-1 -

This system requires that particulate emissions be controlled to 0.15 kg per megagram of limestone feed (0.30 lb/ton). No control of SO_2 is required. The system would use a baghouse, high energy electrostatic precipitator or a water scrubber with an estimated pressure drop of 22 inches of water column (22 IWC). Based on current sales trends it appears that most operators are choosing to use baghouses due to the high operating costs of scrubbers. It is estimated that 80 percent of new plants would comply with this emission limit by using baghouses and that 20 percent would use ESP's. In those states which presently require control at a level slightly lower than this most new plants are using baghouses. However the standard can be met with high energy ESP's which have comparable energy requirements and operating costs. Certain lime manufacturers favor the use of ESP's and will continue to use them.

Control System A-2 -

This system requires that particulate emissions be controlled to 0.25 kilograms per megagram of stone feed (0.5 lb/ton). This is below the level of 0.50 kilograms per megagram of stone feed (1.00 lb/ton) required by the average State regulation. No control of SO_2 is required. This option could be met by a baghouse, low energy ESP, or a water scrubber with a pressure drop of about 15 IWC. It is estimated that 60 percent of U.S. lime manufacturers would comply with this alternative by using a baghouse, 20 percent would use the low energy ESP, and 20 percent would use a scrubber with 15 IWC. Certain manufacturers that have a convenient area for ponding prefer to use scrubbers when they will meet emission standards. Although more energy is required, capital costs and maintenance are less.

Control System B-1 -

This system requires both SO_2 control to 100 ppm and particulate control to 0.15 kg per Mg of stone feed (0.30 lb/ton). Plants burning low sulfur coal (1.0 percent S and below) can normally meet this alternative by using a baghouse, high energy ESP, or high pressure drop (22 IWC) water scrubber. Plants burning higher sulfur coal may have to use a scrubber. It is expected that 50 percent of the industry will use 22 IWC water scrubbers, 40 percent will use baghouses and 10 percent will use high energy electrostatic precipitators. Plants burning higher sulfur coal that have to use a water scrubber may choose to use a combination baghouse and low pressure drop SO_2 scrubber in order to comply with the SO_2 emission limit instead of using a 22 IWC water scrubber.

Control System B-2 -

This system requires SO_2 control to 100 ppm and particulate control to 0.25 kg per megagram of stone feed (0.50 lb/ton). Plants burning low sulfur coal (1.0 percent S and below) can comply with this alternative by using a baghouse, low energy ESP, or medium pressure drop (15 IWC) water scrubber. It is expected that 60 percent of these plants would use 15 IWC water scrubbers, 30 percent would use baghouses, and 10 percent would use electrostatic precipitators. Plants burning higher sulfur coal may have to use a 15 IWC water scrubber to insure compliance with the SO_2 limitation, thus the high percentage of plants using scrubbers.

Control System C -

Plants burning high sulfur or low sulfur coal can meet the average present State regulation by using a baghouse, low energy ESP, low pressure drop (9 IWC) water scrubber, or a gravel bed filter. It is expected that if only State regulations remain in effect that 60 percent of the industry would use baghouses, 20 percent would use low energy ESP's, and 20 percent would use low pressure drop 9 IWC water scrubbers.

6.1.2 Air Pollution Impact

To determine the actual emission reduction that would be achieved by each of these alternative emission control systems, it is necessary to estimate the reduction in air pollution beyond that which would otherwise be achieved by State or local regulations.

It is assumed that by 1987 the entire lime industry will be using coal as fuel and that one-half of the coal will have sulfur contents ranging from 1.0 to 4.0 percent. The average sulfur content of the high sulfur coal is expected to be as high as 3 percent.

6.1.2.1 Estimated Emission Reduction in 1987 -

The values for the 1987 total lime and hydrate production and the production subject to any control option are developed in Chapter 7, Economic Impact. Lime production capacity is expected to grow at a rate of 3.6 percent compounded with a base of 24,166,000 tons in 1977 and hydrate production capacity is expected to grow at a rate of 1.6 percent with a base of 2,891,000 tons in 1978. It is predicted that the equivalent of eight new 500-ton-per-day kilns will be built in 1977 and that the equivalent number built per year will increase to twelve in 1987. The rotary kiln emission factors for all applicable control devices are discussed in detail in Chapter 4 and Chapter 7 and summarized in Table 6-3.

The results of these impact calculations for United States emissions in 1987 are shown in Table 6-4. When compared to Alternative C, all of the remaining four alternative systems of emission reduction (described in 6.1.1) show a reduction in 1987 particulate emissions (positive impact) ranging from

Table 6-3. ROTARY KILN FACTORS

	Emission factors			Electrical energy factors
		Pounds SO_2 per ton stone		
	Pounds particulate per ton stone	Low sulfur coal	High sulfur coal	Kilowatt hours per ton stone
Uncontrolled (cyclone only)	34.1	-	-	16 [1]
Baghouse	0.3	1.0	2.0	2.42
Electrostatic precipitator (high energy)	0.3	-	-	3.19
Electrostatic precipitator (low energy)	0.5	-	-	2.21
Water scrubber 22 IWC	0.3	0.1	0.1	15.2
Water scrubber 15 IWC	0.5	0.1	0.1	10.8
Water scrubber 9 IWC	1.0	0.1	0.1	6.45
Gravel bed filter	1.0	-	-	-

[1] Electrical energy required for kiln and associated equipment.

Table 6-4. REDUCTION OF PARTICULATE AND SO_2 EMISSIONS OF FOUR CONTROL SYSTEMS COMPARED TO STATE REGULATIONS FOR ROTARY LIME KILNS IN UNITED STATES 1987

Control system	Control required			Particulate[1] impact tons	SO_2[2] impact tons
	kg/Mg	lb/ton	ppm SO_2		
A-1	0.15	0.30	-	10,000	0
A-2	0.25	0.50	-	7200	0
B-1	0.15	0.30	100	10,000	7200
B-2	0.25	0.50	100	7200	7200
C[3]	0.5	1.00	200	0	0

[1] Particulate impact calculated by comparing system to state regulation.

[2] SO_2 impact calculated by comparing emission limit (100 ppm) to amount emitted from that half of industry burning high sulfur coal (200 ppm).

[3] State regulation.

7200 to 10,000 tons a year. The impact on SO_2 emissions ranges from no impact to a reduction of 7200 tons.

6.1.2.2 Impact on Model Plant -

The effect of the various alternative emission control systems on the emissions from the model rotary kiln (1000 tons of stone feed per day, 500 tons per day of lime product) are shown in Table 6-5. Particulate emissions are reduced by 50 percent under Alternatives A-2 and B-2 and by 70 percent under Alternatives A-1 and B-1. As discussed earlier, the reduction in SO_2 emissions would potentially occur only in plants burning coal with a sulfur content of more than 1 percent. Alternatives B-1 and B-2 would result in an SO_2 emission reduction of 50 percent in plants burning 3 percent sulfur coal.

6.1.2.3 Impact on Air Quality -

A meteorological dispersion model has been used by the U. S. EPA Source - Receptor Analysis Branch for the evaluation of the alternative systems of emission reduction outlined in Section 6.1.1. The specific model employed was the aerodynamic-effects version of the Single Source Dispersion Model (CRSTER), that was developed by the Meteorology Division, EPA. This is a Gaussian type model capable of considering multiple emission points and complex aerodynamic effects. Assumptions made in this application of the model include the following:

1. Emission rates are constant.
2. Pollutants are nonreactive and non-depleting.
3. Terrain is relatively flat.

The model is programmed to use a previously determined set of dispersion conditions derived from the basic meteorological data for each hour of a given year. The calculations simulate the interaction between the plant characteristics and these dispersion conditions to produce a dispersion pattern for each hour. These computations are performed for each point in an array of 180 receptors encircling the plant. Cumulative averages are calculated at each of the receptors for any number of hours. In the case of lime plants, the averaging periods of interest are 1 hour, 3 hours, 8 hours, 24 hours, and 1 year.

Lime plants are located throughout the United States, but for the purposes of this dispersion analysis, Austin, Texas, was chosen as the location for the model plant. It was felt that the meteorology at this location was such that it represented an adverse condition for lime plants. The meteorology data used are the actual hour by hour conditions that were recorded at Austin over a one year period.

Dispersion calculations were performed on two separate model plants, one with a typical stack height of 30.5 meters and the other with a taller stack of 51.0 meters. The two models are presented to show the affect on ambient air quality of a typical plant and a plant designed to preclude downwash.

In flat-to-gently rolling terrain, such as that assumed in this analysis, experience indicates that the model estimates are reliable to within a factor of about two. However, the direct extrapolation of the results to actual plants should not be attempted. Such extrapolation could lead to seriously erroneous estimates, since plants vary considerably in their characteristics and in their location with respect to large and small scale meteorological features. Actual plants should be modeled on a case-by-case basis. Nevertheless, this dispersion analysis of the lime industry gives a relative feeling for the effect that the different systems of emission reduction will have on air quality so that they can be compared with each other and with the emission levels specified by State regulations.

The National Ambient Air Quality Standards (NAAQS) establish the maximum concentration of a pollutant that is to be found in the ambient air. The Primary and Secondary AAQS are for health and welfare effects, respectively. Since there are varying amounts of background pollution across the United States, a lime plant in a "clean" area can emit more than one located in "dirty" area without exceeding the AAQS. Another yardstick, the Significant Deterioration Increment (SDI), has therefore received consideration. The SDI specify the maximum additional pollutant concentration a single source can add to the ambient air. The SDI are especially critical for lime plants since they are normally located in rural areas where there is little background pollution.

A summary of the results of the model kiln dispersion analysis is shown in Table 6-6. In this table air quality impact is shown as the maximum pollutant concentration in micrograms per cubic meter ($\mu g/m^3$) and the distance in kilometers from the stack at which this maximum was found. The pollutant concentrations that result from kilns controlled to meet the five alternative systems of emission reduction are compared to pollutant concentrations of the Primary and Secondary AAQS and the SDI. Results are shown for both dry (baghouse, ESP) and wet (water scrubbers) collectors. The pollutant concentrations resulting from all of the emission control alternatives fall below the AAQS. When a typical kiln is not designed to preclude downwash, the SDI for particulate and sulfur dioxide (SO_2) may be threatened. The particulate concentrations for alternatives A-1 and B-1 and the SO_2 concentrations for alternatives B-1 and B-2 are the only ones that are well below the SDI.

Table 6-5. EMISSIONS FROM MODEL KILN BURNING 3 PERCENT SULFUR COAL

Control system	Control required			Particulate emissions		Decrease in particulate emissions from state regulations	SO_2 emissions		Decrease in SO_2 emissions from uncontrolled
	kg/Mg feed	lb/ton feed	ppm SO_2	kg/hr	lb/hr		kg/hr	lb/hr	
A-1	0.15	0.30	-	5.7	13	70%	38	84	-
A-2	0.30	0.50	-	9.4	21	50%	38	84	-
B-1	0.15	0.30	100	5.7	13	70%	19	42	50%
B-2	0.30	0.50	100	9.4	21	50%	19	42	50%
C/1	0.50	1.00	200	19	42	-	120	257	-

/1 State regulations

Table 6-6. AIR QUALITY IMPACT - MODEL 500 TPD ROTARY LIME KILN

Pollutant	Averaging Time	Type Collector	Distance To Maximum Concentration (Km)/1	Impact of Kiln Controlled To Meet Emission Control Alternative /4 ($\mu g/m^3$)					Primary AAQS/3 ($\mu g/m^3$)	Secondary AAQS ($\mu g/m^3$)	Significant Deterioration Increment ($\mu g/m^3$)
				A-1	A-2	B-1	B-2	C/2			
Particulate	24 hr.	Dry	2.0	7.7(0.8)	13 (1.4)	7.7(0.8)	13 (1.4)	26 (2.8)	260	150	30
		Wet	0.9	13 (1.7)	21 (2.9)	13 (1.7)	21 (2.9)	42 (5.7)			
	Annual	Dry	2.0	0.9(0.1)	1.4(0.2)	0.9(0.1)	1.4(0.2)	2.9(0.4)	75	60	10
		Wet	0.9	2.1(0.3)	3.5(0.5)	2.1(0.3)	3.5(0.5)	6.9(0.9)			
Sulfur Dioxide	3 hr	Dry	0.9	105(20)	105(20)	53 (10)	53 (10)	105(20)		1300	700
		Wet	0.9	212(45)	212(45)	106(23)	106(23)	212(45)			
	24 hr	Dry	2.0	52 (5.6)	52 (5.6)	26 (2.8)	26 (2.8)	52 (5.6)	365	260	100
		Wet	0.9	85 (11)	85 (11)	42 (5.7)	42 (5.7)	85 (11)			
	Annual	Dry	2.0	5.8(0.9)	5.8(0.9)	2.9(0.4)	2.9(0.4)	5.8(0.9)	80	60	15
		Wet	0.9	14 (1.8)	14 (1.8)	6.9(0.9)	6.9(0.9)	14 (1.8)			
Carbon Monoxide	1 hr	Dry	0.9	52 (6.6)	52 (6.6)	52 (6.6)	52 (6.6)	52 (6.6)	10,000		
		Wet	0.9	87 (16)	87 (16)	87 (16)	87 (16)	87 (16)			
	8 hr	Dry	0.9	18 (2.7)	18 (2.7)	18 (2.7)	18 (2.7)	18 (2.7)	40,000		
		Wet	0.9	30 (6.1)	30 (6.1)	30 (6.1)	30 (6.1)	30 (6.1)			
Nitrogen Oxides	Annual	Dry	2.0	4.1(0.6)	4.1(0.6)	4.1(0.6)	4.1(0.6)	4.1(0.6)	100		
		Wet	0.9	10 (1.3)	10 (1.3)	10 (1.3)	10 (1.3)	10 (1.3)			

/1 Distances for no downwash case, for downwash all maximum concentrations are at 0.2 Km.
/2 Controlled to meet average state regulations.
/3 AAQS - Ambient Air Quality Standards.
/4 Concentrations in parenthesis are for no downwash case.

6.1.3 Water Pollution Impact

None of the alternative emission control systems have an adverse impact on water quality. Baghouses (fabric filters), electrostatic precipitators, and gravel bed filters have no water effluent. If water scrubbers are used for rotary kiln emission control, the plant may be required to discharge or treat a liquid stream. Normally, however, lime plants using water scrubbers operate closed water systems with total recycle. In this method of operation, the waste water system and solid waste handling system are integrated into a single system. The entrained solids are removed from the water in a settling pond (or settling tank). After a substantial portion of the solids have settled out the water is returned to the process for further use or to storage for additional solids settling and subsequent reuse. The accumulated solids are removed periodically, at which time they become a solid waste problem (see Solid Waste Impact, Section 6.1.4). Overflow from the ponds can be prevented by preventing excess rain water or ground water from entering the ponds.

The EPA Effluent Guidelines development document on waste water effluent from lime plants concludes that zero waste water effluent should be the standard for the industry.[1]

6.1.4 Solid Waste Impact

When scrubbers, precipitators, fabric filters, or gravel bed filters are used to control emissions from lime kilns, solid waste will be generated.

6.1.4.1 The Amount of Material Collected -

Table 6-7 shows the amount of solid waste collected for each of the alternative emission control systems presented in this chapter. For the purpose of this table it is assumed that a plant conforming to the State regulations (Alternative C) will collect 340 pounds of dry solids per ton

Table 6-7. SOLID WASTE IMPACT ON MODEL ROTARY KILN

Emission Control Alternative	Emission Control Device	Solid Waste Collected (kg/hr)	Increase Above State Reg
A-1	ESP, Baghouse	3220	>1%
B-1	Scrubber	4000	25%
A-2	ESP, Baghouse	3210	>1%
B-2	Scrubber	3980	25%
C/1	ESP, Baghouse Gravel Bed Filter	3200	-

/1 State Regulations.

of lime. The table shows that a dry collector used for Alternative A-1 increases the amount of solid waste collected by very little, less than 1 percent. If a scrubber is used for Alternative B-1, then the amount of solids produced will be greater because the water in the scrubber will react with the CaO and other compounds to form hydroxides and hydrates. The pond sludge which the scrubber produces also contains some water which is difficult to remove and also increases the weight of the waste. No information is available on the wet weight of the sludge produced by a scrubber, but if some assumptions are made in regard to the composition of the dust it can be calculated that the weight of sludge produced is about 25 percent more than the weight of the equivalent dust. There will be no appreciable increase in solid waste when dry collectors are used for Alternative A-2 but there will again be an increase of about 25 percent when scrubbers are used for Alternative B-2.

6.1.4.2 The Uses of the Material Collected -

At the present time some lime producers that recover dry particulate from the control devices are able to find uses for this material. At least one plant briquettes the dust and feeds it back into the kiln to be converted to product.[2] Most lime producers cannot do this because the dust contains much more sulfur than the lime product and recycling the dust may increase the sulfur content so that the lime will not meet product specifications. Some lime producers use the lime dust as a raw material in cement kilns.[3] This method of disposal can only be used if the lime plant and cement plant are close together. The dust has little value as cement kiln feed and it is not profitable to transport the material very far. Some manufacturers sell the dust for agricultural liming[4] but this market is seasonal and during most of the year the dust must be disposed of in other ways. At least one manufacturer wets and granulates the dust and uses it for metallurgical purposes[5] but the demand for material for this use is limited. Another manufacturer plans to wet and granulate the material (from a kiln calcining a dolomitic stone) and use it as a magnesium source in blended fertilizer.[6] At least one manufacturer uses the dust to neutralize acid water discharged from a steel mill.[7]

No reliable data are available on what part of the dry material collected by the lime industry is put to use. Many of the plants which collect dry material dispose of the dust by dumping it back into a mined out quarry or some other convenient location.

When scrubbers are used for emission control the solid waste produced is in the form of a wet sludge dredged from the settling ponds. One of the plants visited in the preparation of this work used this material for soil stabilization.[8] Other plants dispose of the sludge in landfills or in mined out quarries. The material is not used for most of the purposes for which the dry waste is used because it is difficult to handle when wet, expensive to dry, often contaminated with the pond bottom and not available on a day by day basis. (Ponds are dredged only periodically, the dust product of dry collectors is available every day.)

6.1.4.3 Impact of the Alternative Emission Control Systems -

The impact of the four alternatives on the required amount of solid waste disposal depends on how many plants would elect to use scrubbers. With either Alternative B-1 or B-2 all plants burning coal with a sulfur content over one percent would probably use scrubbers. The amount of material collected would increase significantly and there may be less use for the material collected.

The problem of disposing of this sludge to some extent is similar to the problem of disposing of the sludge from lime slurry scrubbing systems for coal-fired steam generators except that less sludge is generated from lime kiln scrubbers. The technology available for scrubber sludge disposal have been studied thoroughly[9,10] and the EPA has concluded that the sludge can be disposed of in an environmentally acceptable manner by hardening the sludge and using it for landfill.[11]

With either Alternative A-1 or A-2 no scrubbing would be required, a maximum of 1.0 percent additional solids would be collected, and there would not be a significant impact on the amount of solid waste disposal required.

6.1.5 Energy Impact

All of the control devices used in the four alternative emission control systems use electrical energy and with three of the alternatives there will be an increase in the electrical energy required compared to that required by State regulation. In this section there is a comparison of the energy increase required by all affected U.S. lime plants in 1987 and the energy increase required by a model lime plant for the four control systems.

6.1.5.1 Impact on 1987 U.S. Energy Use -

The impact calculations have been made for the year 1987 using the Chapter 7 estimates of production subject to control. The energy values required for each of the control devices are developed in Chapter 7 and summarized in Table 6-3.

Table 6-8 compares the energy requirements of the five alternative emission control systems in 1987. The values are millions of kilowatt hours (kw hr) for that year and for that part of the industry that would be subject to any new emission limit. Alternative A-1 shows a slight beneficial impact (decrease in energy use) because with this system producers will tend to use baghouses or ESP's rather than using scrubbers which require more energy. Producers will use low pressure scrubbers to meet State regulation (Alternative because they have low capital costs that negate the cost of increased energy consumption. Alternatives B-1 and B-2 require more electrical energy than A-1 and A-2 because scrubbers are required if sulfur removal is necessary and the scrubbers require more energy than baghouses or ESP's.

Table 6-8. ELECTRICAL ENERGY IMPACT

Alternative Emission Control System		1982 Impact 10^6 kwhr	1987 Impact 10^6 kwhr
A-1	Baghouse or ESP	+8[2]	+17[2]
A-2	Baghouse, ESP or 15 IWC scrubber	-11	-25
B-1	22 IWC scrubber baghouse or ESP	-75	-164
B-2	15 IWC scrubber baghouse or ESP	-59	-129
C[3]	9 IWC scrubber baghouse or ESP	-	-

[1] The percent controlled by each device given in Section 6.1.1 and the energy required by each device given in Table 6-3.

[2] Positive impact shows that system uses less energy than plants controlled to State regulations.

[3] State regulations.

6.1.5.2 Impact on Model Plant -

Table 6-9 shows how the energy requirement of a model plant (1000 tons per day stone feed) would increase with each of the alternative emission control systems. The electrical energy, including that used for the plant and the control device, would increase very little for Alternatives A-1 and A-2, but would be more for Alternatives B-1 and B-2 which require scrubbers

Table 6-9. ELECTRICAL AND TOTAL ENERGY USE FOR MODEL ROTARY KILN

Alternative emission control system	Method of control	Electrical energy required per day/1 kw hr	Increase electrical energy from State regs.	Total fuel and electrical energy per day/2 10^6 Btu	Total fuel and electrical energy increase from State regs.
A-1	Baghouse	18,400	1.0%	3,430	-
A-2	Low energy ESP	18,200	-	3,430	-
B-1	22 IWC scrubber	31,200	171%	3,560	4%
	ESP and 9 IWC scrubber in series	24,700	136%	3,500	2%
B-2	15 IWC scrubber	26,800	147%	3,520	3%
C	Low energy ESP	18,200	-	3,430	-

/1 Includes electrical use for plant and control device. Electrical use of various systems given in Table 6-3.

/2 Electrical energy in kw hrs is converted "back" to coal energy in Btu's using typical "fuel factor" for electric generating plants of 10,000 Btu (coal) per kw hr. Fuel required for kiln is 6.5 x 10^6 Btu/ton (lime) for model plant.

if sulfur removal is necessary. The table also shows how the total energy required by the plant would increase for each of the alternatives. In this comparison the electrical energy in kilowatt hours is converted to an equivalent Btu value using a conversion efficiency typical of existing coal fired power plants. Fuel required for the model kiln is 6.5×10^6 Btu per ton of lime produced. The alternative with the maximum energy use (B-1) requires only a 4 percent increase in total energy consumption when high energy scrubbing is used for control. If a combination of low energy ESP and 9 IWC scrubber is used for control there would be only a 2 percent increase in total energy consumption.

The increased electrical energy required for the control systems would probably be generated in coal burning power plants which themselves emit particulate, SO_2 and NO_x. The amount of emissions generated by a power plant producing the electricity required to operate a control device can be calculated. These power generation emissions can then be compared with the reduction in emissions caused by the control device. For the 500 tons a day lime kiln, the highest energy Alternative, B-1, with a 22 IWC scrubber, requires 13,000 more kilowatt hours per day than State regulations (Alternative C). If the power plant generating this electricity is operating in conformance to New Source Performance Standards then the power plant can emit no more than 2.1 pounds of total emissions (particulate, SO_2, NO_x) per million Btu heat input.[12] If the power plant uses 10,000 Btu to produce one kilowatt hour then it may emit 2.0 pounds total emissions per 1000 kilowatt hours of electricity. The increase in electrical energy of 13,000 kilowatt hours per day is therefore equivalent to an increase of 10.8 pounds of emissions per hour from the power plant. For the model plant, Alternative B-1 reduces SO_2 emissions by 42 pounds an hour and particulate emissions by 21 pounds an hour for a total reduction of 63 pounds an hour. (From Table 6.5) The increase in emissions from the generation of the additional electrical energy required for control is small compared to the kiln emission reduction which results from the control.

6.1.6 Other Environmental Concerns

6.1.6.1 Irreversible and Irretrievable Commitment of Resources

The first four alternative systems of emission reduction will require equipment of higher efficiency than that required by alternative C (State regulations). The additional steel and other materials and the amount of additional space needed for the higher efficiency devices is expected to be minor. The steel can eventually be salvaged and recycled.

The emission control devices used in the four alternative systems of emission reduction will require increased usage of electrical energy which is a limited resource. This energy is irretrievable but its use will result in a significant reduction in the amount of particulate matter emitted from a lime plant. Compared to the total plant energy use, amount of electrical energy used to operate these control devices is negligible.

6.1.6.2 Environmental Impact of Delayed Standards -

Delaying the proposal of one of the four alternative systems of emission reduction will result in increasing the emissions of particulate matter from lime plants. Based on the growth projections presented in Chapter 7, the adverse environmental impact of delayed implementation of the emission limit is shown in Table 6-10. The other environmental impacts of the alternative systems of emission reduction are small so that delaying the proposal will not result in an appreciable reduction in any negative impacts. Furthermore, there does not appear to be any emerging emission control technology that could achieve greater emission reductions or result in lower costs than that represented

Table 6-10. ENVIRONMENTAL IMPACT OF DELAYED OR NO STANDARDS FOR ROTARY LIME KILNS[1]

Year	Affected Production[2] (1000 Mg/yr)		Particulate Impact (Mg/yr)		SO_2 Impact[3] (Mg/yr)	
	Yearly	Cumulative	Systems A-2, B-2	Systems A-1, B-1	Systems A-1, A-2	Systems B-1, B-2
1978	1144	1144	572	801	0	572
1979	1185	2329	1736	2431	0	1736
1980	1229	3558	3515	4921	0	3515
1981	1273	4831	5930	8303	0	5930
1982	1318	6149	9004	12,607	0	9004
1987	1573	13,487	35,126	49,176	0	35,126

[1] The increase in emissions caused by delaying the standards.

[2] Based on Table 7-6.

[3] Based on 50 percent of the industry using high sulfur coal.

by the emission control alternatives under consideration here. Therefore, since delaying the proposal to allow further technical developments appears to present no potential benefit, and since it would increase the emissions of particulate matter, delaying the proposal does not appear to be warranted.

6.1.6.3 Environmental Impact of No Standard

Based on the growth projections presented in Chapter 7, the adverse environmental impact of no standard is summarized in Table 6-10. Since there are little adverse water pollution and solid waste impacts, and only moderate energy consumption impacts associated with each of the alternative emission control systems which could serve as a basis for the standards, not setting standards presents little trade off of potentially adverse impacts in these areas against the resulting adverse impact on air quality.

6.2 IMPACTS OF CONTROL TECHNOLOGY FOR LIME HYDRATORS

In Chapter 4 there is a discussion of the use of water scrubbers to control the particulate emissions from lime hydrators. (There are no SO_2 emissions from hydrators.) Although the off-gas stream from a hydrator can be controlled by a baghouse, the water scrubber has several advantages which make it more suited for this application. The water slurry from the scrubber can be used as part of the make-up water required for the hydration. No settling ponds are required and there is no solid waste impact or water impact. The water scrubber is not effected by the condensation which is apt to occur in the high moisture hydrator off-gas.

There are two alternative levels of emission control, both of which utilize a water scrubber, presented for the control of lime hydrator off-gas. The scrubbers described in Chapter 4 which can be used for this application reduce particulate to 0.15 pounds per ton lime feed (Alternative I). For the

14 tons per hour (lime feed) model hydrator the average State regulation will allow 1.0 pound of particulate emissions per ton of lime feed (Alternative II).[13]

6.2.1 Impact on 1987 U. S. Emissions

In Chapter 7, Economic Impact, it is projected that there will be 635,000 megagrams (775,000 tons) of hydrate production subject to the emission limit in 1987. The reduction in particulate emissions from this affected production is shown in Table 6-11. The table shows that there will be a particulate emission reduction of 251 megagrams (276 tons) for the year 1987.

Table 6-11. 1987 REDUCTION OF PARTICULATE EMISSIONS
FOR LIME HYDRATORS IN UNITED STATES

Alternative emission control system	Emission limit		Particulate impact tons
	kg/Mg lime feed	lb/ton lime feed	
I	0.075	0.15	276/1
II/2	0.50	1.00	-

/1 Assumes 1 pound lime yields 1.25 pound hydrate
/2 State regulations.

6.2.2 Impact on Model Plant

The effect of each of the alternative emission control systems on the emissions from the model hydrator (14 tons of lime feed per hour, 17 tons per hour of product) are shown in Table 6-12. Alternative I reduces particulate emissions by 85 percent over Alternative II (State regulations).

Table 6-12. PARTICULATE EMISSION FROM A MODEL LIME HYDRATOR

Alternative emission control system	Allowed emission kg/hr	Allowed emission lb/hr	Decrease from State regs.
I	0.96	2.1	85%
II[1]	6.4	14	-

[1] State regulations.

6.2.3 Impact on Air Quality

The dispersion model described in Section 6.1.2.3 was also used to determine the air quality impact of a typical lime hydrator. The results of these calculations are shown in Table 6-13. Although none of the concentrations approach the ambient air quality standards, the significant deterioration increment may be exceeded for emission control alternative II (average state regulations) if downwash is allowed to occur.

Table 6-13 - AIR QUALITY IMPACT - MODEL 17 TPH LIME HYDRATOR PARTICULATE CONCENTRATIONS

Emission Control Alternative	Averaging Time	Downwash		No Downwash		Primary AAQS ($\mu g/m^3$)	Secondary AAQS ($\mu g/m^3$)	SDI ($\mu g/m^3$)
		Maximum Concentration ($\mu g/m^3$)	Distance To Maximum (Km)	Maximum Concentration ($\mu g/m^3$)	Distance To Maximum (Km)			
I	24 hr	4.6	0.2	0.5	0.3	260	150	30
	Annual	0.9	0.2	0.1	0.9	75	60	10
II/1	24 hr	30.7	0.2	3.5	0.3	260	150	30
	Annual	6.1	0.2	0.5	0.9	75	60	10

/1 State Regulations

Table 6-14. ENVIRONMENTAL IMPACT OF DELAYED OR NO STANDARDS FOR LIME HYDRATORS[1]

Year	Lime Hydrator Production Affected by Standards (1000 Mg/yr)[2]		Particulate Impact (Mg/yr)
	Yearly	Cumulative	
1978	55	55	18
1979	56	111	56
1980	56	167	113
1981	57	224	189
1982	59	283	285
1987	63	590	1076

[1] The increase in particulate emissions caused by delaying the standards.
[2] Based on Table 7-6.

6.2.4 Other Environmental Impacts

As previously stated there are no solid or liquid waste impacts of Alternative I or II. There is minimal additional electrical energy used in Alternative I compared to Alternative II. No scarce resources will be consumed. Table 6-14 shows the increase in particulate emissions that will occur as a result of delaying the proposal of Alternative I. Since there are no benefits to be derived from delaying the standards and since the emissions of particulate matter will be greater if the standards are delayed, postponing this standard does not appear to be justified.

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10. "Evaluation of Lime/Limestone Sludge Disposal Options," Radian Corp., November 1973 (EPA-450/3-74-016).

11. "New Source Performance Standards for Fossil Fuel-Fired Steam Generators," Federal Register 40 FR 42045 (September 10, 1975).

12. "Standards of Performance for New Stationary Sources," Federal Register 36 FR 24876 (December 23, 1971).

13. "Environmental Impact Statement for Lime Plants," Prepared by Midwest Research Institute for the U.S. EPA, Contract No. 68-02-1324, Task No. 33, December 1975.

7. ECONOMIC IMPACT

7.1 Industry Economic Profile

7.1.1 Introduction

This section provides background information on the character of the firms engaged in the production of lime products, industry organization, plant size and location, markets, production economics, capacity data, and prices. This information will provide the basis for the underlying assumptions and data inputs for the economic analysis in Section 7.4.

7.1.2 Firm Characteristics

The commercial lime industry comprises a large variety of firms. Some are large multi-plant firms whose major business is lime production. Others are small, independent commercial producers. Both types of firms constitute Standard Industrial Classification (SIC) 3274. According to the 1972 Census of Manufacturers, there were 68 companies with 103 plants under SIC 3274.(1) A large sector of the lime industry includes so-called "captive" plants which are a part of vertically integrated operations.(2) Many of the latter are firms whose primary lines of business are beet sugar processing, alkali production, and metals manufacturing (steel, copper, magnesium). As a consequence, information about the operating characteristics of the captive lime industry is either closely held or else combined with the operating data of other company divisions in publicly available financial reports.

7.1.3 Plant Characteristics

As mentioned before, some 103 plants produced lime as a primary product in 1972. The total lime industry comprised some 186 plants in 1972.(3)

According to Bureau of Mines, some 170 plants were operating in 1975.(4) Table 7-1 summarizes the location and characteristics of 177 plants that were active in the first quarter of 1974.(5)

The total capacity of all lime plants (based on the assumption that lime plants operate an average of 330 days per year), as shown in Table 7-1, is 65,859 tons per day or about 22 million tons per year. Of this total, commercial plants account for about 78 percent and captive plants for 22 percent. On the other hand, the number of plants (95 commercial, 82 captive) is about evenly divided between the commercial and captive sectors. The capacity available to produce dead-burned dolomite (about 8 percent of the industry total) is not distinguished according to the market status of the producing firms.

It is notable that the share of capacity represented by rotary kilns differs substantially between the commercial and the captive sectors of the lime industry. Within the commercial sector about 85 percent of total capacity consists of rotary kilns while in the captive sector the corresponding statistic is roughly 54 percent. This disparity is largely accounted for by the fact that many of the captive lime plants are owned by beet sugar companies which generally employ vertical kilns in beet sugar processing.

7.1.4 Industry Organization

The domestic lime industry is generally divided into two marketing sectors: commercial and captive producers. The former group of firms produces lime products primarily for resale to other firms or individual users. (About 85 percent of the tonnage in this sector of the industry is represented by the National Lime Association.) Captive plants, on the other hand, produce lime largely for their own use on the plant site, although some sell part of their output in the open, or commercial,

TABLE 7-1. NUMBER AND CHARACTERISTICS OF LIME PLANTS, BY REGION (1974)

		Commercial plants				Captive plants				
Region	States in region	Number of plants in region	Capacity (tons per day) by kiln type Rotary	Nonrotary	Total (TPD)	Number of plants in region	Capacity (tons/day) by kiln type Rotary	Nonrotary	Total (TPD)	Dead-burn dolomite Capacity (rotary)
1	Connecticut Massachusetts New Jersey New York	3	118	276	394	3	0	200	200	0
2	Pennsylvania	7	4,495	484	4,979	3	2,784	667	3,451	152
3	Maryland West Virginia Virginia	9	1,332	2,592	3,924	1	0	110	110	0
4	Alabama	6	4,313	0	4,313	0	0	0	0	0
5	Florida Kentucky Mississippi Puerto Rico Tennessee	6	1,279	700	1,979	2	588	182	770	0
6	Ohio	11	7,005	2,014	9,019	6	1,061	112	1,173	4,318
7	Illinois Indiana Michigan	9	4,921	999	5,920	6	492	76	568	182
8	Wisconsin	5	521	294	815	1	*	*	neg.	0
9	Iowa South Dakota	2	576	20	596	1	0	45	45	0
10	Missouri	4	5,987	536	6,523	0	0	0	0	182
11	Arkansas Louisiana Oklahoma	4	1,233	250	1,483	4	756	1,584	2,340	0
12	Texas	8	2,141	288	2,429	6	661	75	736	0
13	Colorado	0	0	0	0	11	0	905	905	0
14	Minnesota Montana Nebraska North Dakota Wyoming	1	96	*	96	14	664	592	1,336	0
15	Arizona	4	1,405	0	1,405	4	7	125	132	0
16	Nevada Utah	7	1,807	184	1,991	1	182	60	242	0
17	Idaho New Mexico	1	0	0	0	5	0	185	185	0
18	Hawaii Oregon Washington	5	252	535	787	3	60	60	120	0
19	California	3	300	200	500	10	94	1,056	1,150	182
20	Kansas	0	0	0	0	1	*	75	75	0
	Total U.S.	95	37,781	9,372	47,153	92	7,329	6,209	13,538	5,168

Neg. - negligible.
*The distribution of capacity between rotary and vertical kilns is unknown.

Data Source: Research Triangle Institute market. The share of output accounted for by these producers effectively measures the degree of forward vertical integration. This share has remained relatively stable, between 34 and 40 percent of industry output during the past 10 years.

Many of these captive producers have lime kilns on the plant site. These kilns are often essential because lime calcination is one of the few practical means of generating a large volume of carbon dioxide gas--a co-product, with lime, of the calcination process. Both alkali production and beet sugar processing are characteristic of processes which require a large volume of CO_2. These two industries alone account for about 59 of the 177 domestic lime plants.(6)

Other major lime consuming industries which maintain lime production facilities include copper, steel, and calcium carbide manufacturers. The market share trends accounted for by captive producers in each sub-market are discussed more completely below.

The degree of backward vertical integration is more difficult to quantify. However, a significant proportion of lime plants do have associated primary and secondary limestone crushing facilities. In addition, several lime producing firms have stone quarrying operations. Thus, it appears that most lime plants are part of a fully integrated limestone processing operation.

Among companies which produce lime products--those with 3274 Standard Industrial Classification (SIC) codes--most derive a large portion of their sales from mineral product-related activities. The most important among these are crushed and broken limestone (SIC 1422); hydraulic cement (SIC 3241); quarrying of broken and crushed stone (SIC 1422); quarrying construction sand and gravel (SIC 1442); crushing and grinding of stone, etc. (SIC 3295); clay, ceramic, and refractory minerals (SIC 1459); ready mixed concrete manufacture (SIC 3273); and mining crushed and broken stone (SIC 1429).(7)

Table 7-2 provides historical data on the degree of concentration in the lime industry.(8) The concentration ratios presented there measure the percentage of total industry sales accounted for by the 4, 8, 20, and 50 largest companies in the industry. These concentration ratios are rather low by comparison to many industries. Also, it appears that concentration in the industry peaked during the period from 1954 to 1958 and has generally fallen since then.

7.1.5 Production Economics

Each year since 1929 the Bureau of Mines has canvassed the lime industry to determine the number of plants and the ouput of plants by size category. Consequently, the shares of industry output accounted for by each size class were analyzed directly.(9) The analysis was conducted for each of five size classes: plants producing less than 10,000 tons per year; 10,000 - 25,000 tons per year; 25,000 - 50,000 tons per year; 50,000 - 100,000 tons per year; and more than 100,000 tons annually. The output shares accounted for by the first three sizes classes have declined markedly during the period 1930 - 1972. The fourth size class (50 - 100,000 tons per year) has accounted for an erratic share of output over time while the largest size class (greater than 100,000 tons per year) has clearly been growing steadily over time. A conclusion from the analysis is that the trend is toward new plants greater than 300 tons per day. Plant size has been increasing steadily and should continue to do so.

Table 7-2. HISTORICAL CONCENTRATION RATIOS IN THE COMMERCIAL LIME INDUSTRY (SIC 3274)

Year	Number of companies	Value of shipments accounted for by 4 largest companies, percent	8	20	50	Primary product specialization ratio, percent[a]	Coverage ratio, percent[b]
1972	68	37	53	79	99+	89	92
1967	78	35	54	79	99	87	93
1966	NA	31	47	NA	NA	NA	NA
1963	81	37	56	82	99	82	94
1958	94	38	57	80	98	84	95
1954	113	35	53	80	NA	84	97
1947	132	30	47	69	NA	83	97

NA: Not Available

Notes:

a. Specialization Ratio: Value of primary product shipments as a percent of total value of shipments.

b. Coverage Ratio: Value of lime product shipments produced in the lime industry as a percent of aggregate national lime product shipments.

Source: 1972 Census of Manufactures, Concentration Ratios in Manufacturing, Part 1, Special Report.

Table 7-3 shows a breakdown for major components of lime production costs in the commercial lime industry. The actual data from the Census of Manufacturers for 1972 was adjusted to project estimates for 1975. Wholesale price indices (10) were used to make the necessary adjustments in the 1972 expenditures for salaries and wages, materials, and energy. Bureau of Mines production and price data (See Section 7.1.6) were used to estimate value of shipments for 1975. The 1975 entry for depreciation, interests, etc. (capital related and other fixed costs) was determined by deduction of all other costs (percentages) from the 1975 value of shipments (100 percent). The most significant aspect of the data presented in Table 7-3 is the increase in the energy component--from 16.8 percent in 1972 to 28.4 percent in 1975. This observation suggest that energy utilization will be one of the most important forces that will influence future production and investment trends in both the commercial and captive lime industry.

Table 7-4 reports aggregate plant and equipment expenditures in the commercial lime industry between 1958 and 1973.(11,12) The substantial increase in investment during 1972 was likely required to install air pollution control devices and to install larger, more efficient kilns to replace ones whose obsolescence was accelerated by the enforcement of air pollution control regulations in the State Implementation Plans.

7.1.6 Lime Products Markets

The four traditionally identified major uses of all types of lime products (quicklime and hydrated lime) are in agricultural, construction, chemical and metallurgical, and refractory applications. However, as shown in Figure 7-1 agricultural applications of lime can no longer be considered significant.(13) In 1971 chemical and metallurgical uses counted for 79 percent of all lime consumption; construction uses, for

Table 7-3. LIME PRODUCTION COSTS AS A PERCENT OF VALUE OF SHIPMENTS FOR SIC3274 ESTABLISHMENTS

Item	1972(1)	1975(2)
Salaries and wages	21.4	17.4
Limestone, containers, and other materials	29.2	25.8
Fuels and Electrical Energy	16.8	28.4
Contract work and resales	0.8	0.7
Depreciation, interests, profits, taxes, insurance, administrative costs	31.8	27.7
Total Value of Shipments ($ millions)	248.9	384.3

(1) Census of Manufactures data.

(2) Projections made by escalation of Wholesale Price Indices, Bureau of Labor Statistics, Department of Labor.

Table 7-4. PLANT AND EQUIPMENT EXPENDITURES IN THE COMMERCIAL LIME INDUSTRY , MILLION CURRENT DOLLARS (SIC 3274)

Year	Total new expenditures	New structures and plant additions	New machinery and equipment	Used plant and equipment
1958	$ 6.4	$ 2.06	$ 4.30	$ 0.39
1959	12.7			
1960	12.1			
1961	7.0			
1962	12.0			
1963	14.7	2.11	12.62	0.35
1964	21.4			
1965	15.7			
1966	22.1			
1967	17.7	2.00	15.6	0.20
1968	18.5			
1969	20.4			
1970	18.2			
1971	12.8			
1972	42.0	4.5	37.6	0.5
1973	23.0			

Source: U.S. Department of Commerce.

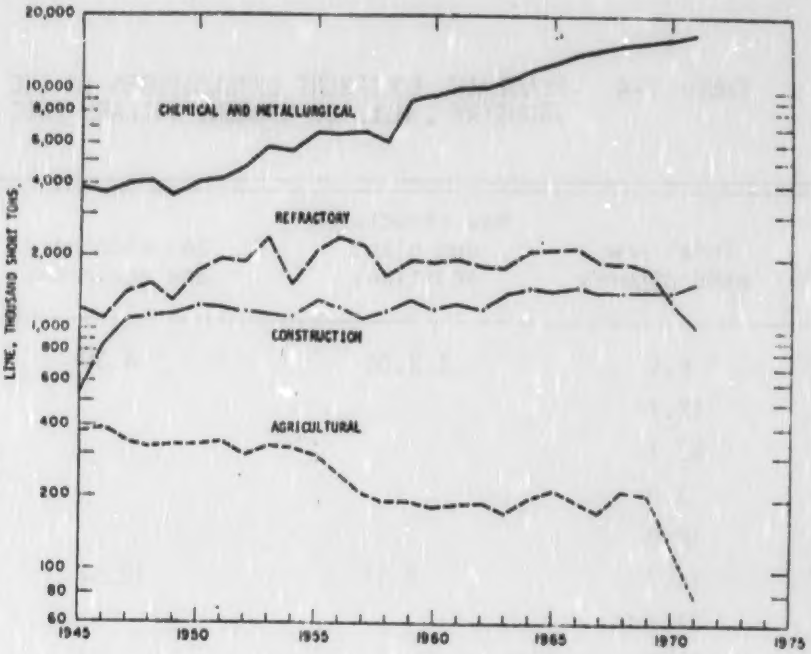

Figure 7-1 Trends in the major uses of lime.

Source: Research Triangle Institute

12 percent; refractory application, for 8 percent; and agricultural uses, for only one percent. Table 7-5 arrays overall consumption and production of lime from 1960 to 1975 in addition to representative prices for open market lime.

The chemical industry is one of the largest single consumers of lime. Lime serves as an important intermediate in the alkali and glass manufacturing industries. Lime also is important in production of acetylene gas, pulp and paper manufacturing, sugar beet processing, and water and waste treatment.

Alkali manufacturers require a large volume of carbon dioxide gas as a basic input to the production of soda ash and bicarbonate of soda. Since CO_2 gas is a low cost by-product of calcination, lime is an obvious choice as one of the industry's main raw materials. Among the four chemical applications of lime, alkali production uses are by far the largest. During the 1960s between 97 and 99 percent of all lime used in alkali production was produced by captive lime plants. Overall these applications account for about 50 percent of all captive lime production and about 15 percent of total lime production. Nonetheless, lime consumption in this sector remained virtually constant throughout the 1960s and offers little future market potential for commercial producers. The reason for this is that trona deposits are replacing the Solvay process as the source of soda ash.

Calcium carbide is an important source of acetylene gas. In producing this product, quicklime is mixed with coke and heated in electric furnaces from which the molten carbide is removed. Total output for this use during 1971 was about 537 thousand tons or about 5.6 percent of all lime produced although 43 percent of that was produced by captive plants. The demand

Table 7-5 HISTORICAL LIME PRODUCTION, CONSUMPTION AND REPRESENTATIVE PRICES (1000 tons)

Year	Consumption	Production	Price ($/ton)
1960	12,906	12,935	13.35
1961	15,200	15,193	13.39
1962	13,812	13,754	13.58
1963	14,609	14,525	13.73
1964	16,200	16,107	13.87
1965	17,057	16,821	13.87
1966	18,223	18,087	13.27
1967	18,080	18,009	13.42
1968	18,680	18,676	13.39
1969	20,383	20,250	13.94
1970	19,936	19,788	14.53
1971	19,811	19,635	15.78
1972	20,542	20,332	16.78
1973	21,429	21,132	17.42
1974	22,029	21,645	22.02
1975	19,433	19,187	27.45

Source: Bureau of Mines

for lime by calcium carbide producers fell at an annual rate of 1.1 percent during the 1960s, reflecting a decline in the demand for acetylene.

In the manufacture of glass, either lime or limestone can be used as fluxing materials. The lime input is used to make glass less brittle and stronger, to reduce its solubleness in contact with chemical solutions, and to provide a more durable lustre in glass. During the 1960s the use of lime in glass manufacture grew rapidly at an average annual rate of 9.8 percent and accounted for about 1.8 percent total lime production during 1971.

Lime is an important water treatment chemical. In many muncipalities it is used as a complement to chlorine treatment to condition water for potable or industrial process uses. One of the major uses is in water softening. In that application lime is used either by itself or with a soda ash reagent, depending upon the degree of hardness of the water. Another application of lime in water treatment is its introduction to retention tanks to purify the water against bacteria. Other uses include its application as a coagulant to remove suspended solids from turbid or reused waste water; as a neutralizer in acidic water; and for silica adsorption and the removal of other waters impurities. In 1970 water treatment uses accounted for approximately 6.2 percent of all lime consumption of which virtually all was purchased from commercial lime plants. Though the annual rate of growth in the demand for lime in water treatment has been erratic, averaging about 2 percent during the 1960s, this market sector is the third largest commercial market for lime and has grown substantially from a consumption level of 710 thousand tons in 1960. The increasing, environmentally related emphasis on water treatment facilities promises a strong demand for lime in this market sector during the next several years.

A related use of lime occurs in small sewage treatment plants which use lime in chemical water treatment processes to coagulate suspended solids. Lime is also used to condition sludge for more efficient disposal. In addition, lime is used for neutralizing acid drainage from coal mines; for treating acidic wastes from metal plating and fabrication and chemical plants; and for coagulation in treating food canning wastes, etc. Although total lime consumption in sewage and trade industrial waste treatment was only about 2 percent of total lime demand in 1971, the annual rate of growth in these applications has been substantial, about 18 percent for the period 1962-71.

Another area which may be a promising potential market is the use of lime for desulfurization of fluegases in power generation as a result of combustion of fossil fuels. Environmental regulations limiting sulfur emissions that have been promulgated as a result of the 1970 Clean Air Act will have to be implemented by flue gas desulfurization because low sulfur fuels may not just be economically available.

Lime demand in the pulp and paper industry is mainly associated with the Sulfate (Kraft) Process wherein lime is used to causticize the "green liquor." Total lime consumption by these manufacturers in 1970 was 918,000 tons, most of which was purchased from commercial producers. However, these purchases are not a good indicator of actual lime consumption since more than 90 percent of thelime entering the process is regenerated. The remaining ten percent that is purchased as "make-up" lime represents the demand level that appears in statistical summaries of lime consumption by this industry. During the 1960s the average annual rate of growth in demand for lime by pulp and paper manufacturers was about 6.7 percent.

The economies of sugar beet processing operations are similar to those associated with alkali plants in that both require large quantities of lime and carbon dioxide gas. This essentially requires captive lime kilns on the plant site, despite the fact that these kilns are often operated only a small number of days per year. Basically, lime is used to remove impurities--phosphatic materials and organic acids--from the crude sugar juices. This entire process, known as defecation and clarification, is often repeated to improve the purity of the sugar solution. Total lime production by sugar beet processors grew at about 3.8 percent annually during the 1960s and represented approximately 4 percent of total domestic lime production in 1971. Nonetheless these captive plants represent about 30 percent of the total number of lime plants. This is due to the fact that sugar beet processors operate on a seasonable basis and their capacity requirements are small. For this reason, sugar beet processors have used vertical kilns, which require lower investment and lower fuel requirements than rotary kilns on a tonnage basis. This trend should continue in the future.

Metallurgical uses of lime, especially as a steel flux, constitute one of the largest and fastest growing market sectors for commercial lime producers. The major uses of lime in metal production are in the manufacture of steel, copper, aluminum, and magnesium.

Lime is used as a flux to purify steel during the heating process.(14) Lime is relatively fast reacting, and facilitates the fusion of the slag and the removal of phosphorus, silica, silicates, etc. in the slag that is tapped off from the molten metal. The widespread acceptance of the basic oxygen furnace (BOF) in the steel industry was, and continues to be, a great boon to the lime industry. As opposed to open hearth furnaces which can economically employ slower reacting limestone as a flux, BOFs which reduce steel heating periods to an hour or less (compared to as many as 8 to 10 hours for open hearths) require the fast reacting characteristics of quicklime. Because the BOF has gained such popularity, it is not surprising that the annual growth rate in lime consumption as a steel flux exceeded 20 percent during the 1960s, accounting for more than 5 million tons of lime usage by 1971. This total currently represents more than 26 percent of all lime production. Unfortunately for commercial producers, however, there has been a correspondingly rising proportion of fluxing lime forthcoming from captive producers. For example, in 1962 that share was about 4 percent but by 1971 it had risen to 19 percent.

Among nonferrous metallurgical applications the use of lime in copper production is the most significant. Generally, in all nonferrous applications, lime is widely used in the flotation (or beneficiation) of the basic ores. Specifically in copper flotation, lime helps to maintain the proper degree of alkalinity. Growth in the rate of lime consumption in cooper production was erratic during the 1960s, averaging about 3 percent annually. In 1971 lime consumption in this use was about 2.5 percent of domestic lime production of which about 55 percent was produced by captive plants. The major share of this captive production principally derives from large western copper companies with lime kilns at the beneficiation mills.

In nearly all commercial magnesium producing processes lime is required as a basic chemical input. The manufacture of aluminum by the Bayer process is also accompanied in a few plants by the use of lime as a caustisizing agent. As a share of total lime consumption neither of these uses, however, constitutes a significant share of lime consumption. Together they account for something on the order of one percent of total demand.

In construction applications, lime is used in masonry mortar, plaster and stucco, and road construction. Each of these areas will be discussed as follows.

Masonry mortar often contains lime in some varying proportion with cement and sand. The proportions chosen depend in part upon the relative prices and supplies of the alternative inputs. They also depend on the desired degree of porosity and the texture of the brick in addition to the desired degree of plasticity in the mortar. Masonry lime demand declined by about 1.6 percent during the 1960s.

Finishing lime is a term generally applied to describe all lime used in exterior plaster, known as stucco, and in interior plaster. As is the case with masonry mortars, lime can be feasibly eliminated altogether from finishing lime mixtures. This factor, coupled with the increasing popularity of gypsum board or dry wall construction in interior applications, has caused a very competitive market situation for lime in finishing and masonry applications. The use of lime for finishing applications declined at an annual rate of 10.8 percent during the 1960s.

A rapidly growing application of lime is in the stabilization of soils in road construction. The two main uses of lime in road construction are subbase stabilization, involving fine-grained soils, and base stabilization, involving clay-gravel type soils. These uses of lime grew at an annual rate of 10.8 percent during the 1960s. The product was mainly produced by commercial lime plants.

Two formerly important uses of lime has been in agriculture, as a soil conditioner, and in steel manufacturing, as a refractory material. The most important reason for decline in agricultural applications has been the substition of limestone as a soil conditioner and heavy use of fertilizers. The decline of lime for refractory material is related to the decline of the open-hearth furnace in steel making. The type of lime used here has been dead-burned dolomite, which is rammed into the furnace to conserve the life of refractory brick. Dead-burned dolomite will still remain a necessary requirement for electric arc furnaces in the future even though open hearth furnaces mostly have been displaced by the BOF.

7.1.7 International Trade

Because of its low value to weight ratio, lime is not an important component of international trade. For example, the value of both exports and imports of lime during 1971 constituted less than a thousandth of a percent of the total value of exports and imports during the year. In spite of environmental regulations confronting the lime industry, it is doubtful whether foreign competition will be a major factor in domestic markets in the foreseeable future.

7.1.8 Growth Trends

Historically, the long-term (since 1930) annual rate of growth in lime production has been approximately 5 percent. Over the 1963-1972 period, demand for quicklime has increased annually at about 4.9 percent; hydrated lime, about 2.2 percent; and dolomite has declined about 8 percent.(15) Overall, total lime industry output has grown at about 3.4 percent. In consideration of future strong markets and the fact that in-roads substitution has probably been complete in certain traditional uses (dolomite and agriculture), a resumption of the historical growth rate of 5 percent seems possible for total lime production in the years ahead.

Chemical and metallurgical industry uses are likely to remain important components of the growth of demand for lime products. However, most of that growth within the chemical industry is likely to remain captive to that industry. On the other hand, metallurgical uses of lime, especially as a steel flux, will be one of the largest and fastest growing market sectors for commercial lime producers. These include lime applications in the manufacture of steel, copper, aluminum, and magnesium.

Other strong future markets for lime products include waste treatment applications and paper and sugar beet processing operations. Among these, the waste treatment applications of lime promise the strongest future market for commercial lime. These applications include water treatment and sewage treatment plant commercial lime. In addition, there is a strong potential market for lime products in sulfur dioxide stack gas scrubbing.

7.1.9 New Sources

Projections for the number of new kilns and hydrators were determined in the following manner. A time series regression of historical capital expenditures (See Table 7-4,) appropriately discounted for inflation by use of the Chemical Engineering Plant Index, was used to predict annual rate of investment in new capacity.(16) A conclusion from this regression is that industry invests in new and replaced capacity at a rate approximately equal to 5.6 percent of existing capacity. This further breaks down to about 3.6 percent for net additions and 2.0 percent for replacement.

The 3.6 percent growth rate is consistent with total industry lime production trends over the 1960 to 1975 period. These estimates were used to project new kiln construction for the 1977 to 1987 time period. See Table 7-6. Demand projections have been made on the basis of a 5.0 percent growth rate, the base production of 1975 and a derived capacity utilization of 84 percent. The year of 1975 represents a lull period because of general recessionary conditions. These demand projections are shown in Table 7-6 for comparison purposes. The effective capacity utilization for 1987 turns out to be 93 percent which may be high but not impossible. In 1974, capacity utilization was almost 100 percent

Projections for hydrators were made in the same manner as for kilns. Existing hydrator capacity is estimated on the basis of reported Bureau of Mines production of 2,353,000 tons per year for 1975, capacity utilization of 84 percent, and a growth rate of 2.2 percent for hydrate. The capacity utilization which is assumed to be the same as for kilns, is derived from lime production and kiln capacity data for 1977. See Table 7-6 for projected hydrators.

Table 7-6. PROJECTED NEW KILN AND HYDRATOR CONSTRUCTION (1978-1987)

	1978	1982	1987
Consumer Demand for Lime Products,(1) 1000 TPY	21,433	26,051	33,249
Existing Kiln Capacity,(2) 1000 TPY (Jan. 1)	25,036	28,841	34,419
Annual New Kiln Capacity,(3) 1000 TPY	1402	1615	1927
a) Replacement (in that year)	501	577	688
b) Net Addition (in that year)	901	1038	1239
Cumulative New Kiln Capacity 1000 TPY (Dec. 31)	1402	7533	16,522
Projected New Kilns, 500 TPD Units/Year (By Dec. 31)	8	10	12
Existing Hydrator Capacity(4) 1000 TPY (Jan. 1)	2891	3080	3335
Annual New Hydrator Capacity, 1000 TPY (in that year)	72	77	83
Cumulative New Hydrator Capacity, 1000 TPY (Dec. 31)	72	371	775
Projected New Hydrators, 17 TPH Units/Year (By Dec. 31)	1	1	1-2

(1) Projected at 5.0 percent compound growth rate with base of 19,440,000 TPY (1976).

(2) Projected at 3.6 percent compound growth rate with base of 24,166,000 TPY capacity on January 1, 1977 (330 days of operation/year).

(3) Derived from historical capital expenditures; investment in new capacity equal to 5.6 percent of existing capacity for any current year.

(4) Projected at 1.6 percent compound growth rate with base of 2,353,000 TPY annual production in 1975; consumer demand for hydrate is projected at 2.2 percent based on previous historical trends, and capacity utilization 84 percent in 1977. 1975 capacity is therefore 2,801,000 tons.

SOURCES: Research Triangle Institute; Environmental Protection Agency.

7.2 COST ANALYSIS OF ALTERNATIVE EMISSION CONTROL SYSTEMS

7.2.1 New Facilities

7.2.1.2 Introduction

This section discusses the development of cost estimates for each of the alternative emission control systems outlined in Chapter 6. While these costs will be based on controlling affected facilities in new plants, the basic cost information presented in this section will also provide the foundation for the analysis of modified and reconstructed facilities in the following section.

The determination of incremental costs for the various control alternatives over state regulations for new sources is a most important element in this section. The incremental control costs are then analyzed for their economic impact upon the viability of the lime industry. All control alternatives must be capable of meeting the no-discharge requirement for water-borne contaminants under EPA effluent guidelines.

7.2.1.2 Model Plants

The economic analysis will focus on plants utilizing rotary kilns for the following product rates: 125 tons per day, 250 tons per day, and 500 tons per day of quicklime. The most representative model plant for new plants being built is the 500 TPD. However, in a few situations small rotary kilns may be built either to satisfy a very small regional market or regeneration requirements for a sugar refiner. The typical hydrate plant can produce 250 TPD of the product.

With today's business environment facing the high cost and unknown availability of clean fuels, lime burning technology is changing to accommodate coal, as the fuel, with high energy utilization. New kilns of short lengths (to reduce radiation losses) combined with stone pre-heater systems, with kiln exit gases heating incoming limestone, are becoming more popular. Long rotary kilns, without preheaters, are being built with better refractory and heat transfer internals. Either way, the trend is toward reduced fuel consumption and the complementary reduced gas cleaning requirements.

The parameters for model plants which are important in the cost analysis are shown in Table 7-7. These parameters are representative of those plants tested in the field (see Appendix C), most of which do not have pre-heater systems. These kilns on the whole would require more combustion air and hence, have higher flow rates than the more fuel-efficient kilns with pre-heaters. As such, control costs in this sense in the report will be representative of recently built plants but may overstate requirements for well-designed fuel efficient kilns in the future.

The model hydrate plant has a design capacity of 17 TPH hydrate with 6000 acfm at 85 percent moisture and a temperature of 210°F. The gas volume for the hydrator is based on reported field data.(17)

7.2.1.3 Control Device Costs

The control technology for this analysis includes baghouses, gravel bed filters, electrostatic precipitators, and venturi scrubbers for the rotary kiln and a centrifugal wet fan scrubber for control of hydrator emissions. The basis for developing control costs were the following sources:

(1) Kiln
  (a) Baghouses(18, 19, 20)
  (b) Electrostatic Precipitators(21,22)
  (c) Venturi Scrubbers(23,24)
  (d) Gravel Bed Filters (25,26)

Table 7-7. LIME KILN MODEL PLANT CHARACTERISTICS

Production Rate, TPD	125	250	500
Heat required, BTU/Ton Lime	6.5×10^6	6.5×10^6	6.5×10^6
Collector Inlet Gas Flow Rate:			
a) SCFM	12,000	24,000	48,000
b) ACFM	23,000	46,000	92,000
Inlet Gas Characteristics:			
a) Moisture, %	13.7	13.7	13.7
b) Temperature, °F	550	550	550

(2) Hydrator

(a) Centrifugal wet fan scrubber(27)

The costs for venturi scrubbers include a lined settling pond which will handle the bleed pump discharge, which is a slurry containing about 5 percent solids at a rate of 300 gallons per minute (on the basis of the 500 TPD model plant). Periodically, solids will be removed by dredging and trucked to a nearby landfill site. Water in the settling pond is assumed to be recycled for the scrubber. The size of the pond is assumed to be 2 acres for the 500 TPD plant.

The capital costs presented in this chapter are based on turnkey bids for new systems on new plants. Direct costs which are based on vendors' quotations include materials and labor in fabrication and erection of the flange-to-flange control hardware, induced draft fans, ductwork, stack, screw conveyor for dust handling, storage for collected dust, pumps, settling pond, freight, sales, taxes, engineering, field supervision, construction labor fringe benefits, vendors' administrative overhead costs, performance tests, and start-up costs. A charge equal to 35 percent of the direct costs was added for indirect costs--contingency, overtime, administrative overheads incurred by the owner of the new source, interest on construction loans, and site preparation. All capital costs have been indexed to July 1976 via the Chemical Engineering Plant Index.

The annualized costs have been developed along the following assumptions. Capital charges have been calculated on the basis of 100 percent debt financing and recovery of capital by uniform periodic payments (capital recovery factor). For all equipment except scrubbers, equipment life assumed is 20 years;

scrubbers, 10 years. Rate of interest for institutional lending is 10 percent. Electricity costs were assessed on 3¢ per kilowatt-hour basis. Maintenance and labor costs in general were adopted from the Industrial Gas Cleaning Institute(18,22) and GARD, Inc.(24) The only exception here was high efficiency precipitators.

The maintenance costs for high efficiency precipitator was assumed to be twice (or 2 percent of investment) as great as similar costs for moderate efficiency precipitators. A diligent maintenance program consisting of more frequent cleaning, more frequent replacement of wires, greater attention to operation of rappers, and similar vigilance should result in a higher tuned precipitator and increased performance. Maintenance costs for gravel bed filters have not been documented but are claimed by the manufacturer to be low relative to other control devices; accordingly, an estimate of 1 percent of capital investment was assigned.

Property taxes and insurance and administrative overhead costs--operating and maintaining the control equipment and records keeping for emissions tests, monitoring, etc.--are assessed at a rate of 4 percent of capital investment.

Charges for solids disposal have been assessed at $3 per ton for dry solids and $4 per ton for wet solids. These values are based on discussion with the National Lime Association,(28) for dry materials; and TVA studies(29) for flue gas desulfurization systems, for wet solids.

Table 7-8 presents the summary of cost estimates for control devices on rotary kilns. For baghouses on the 125 ton-per-day unit, much of the control device is factory assembled; for other applications, field erected.

TABLE 7-8. SUMMARY OF COSTS FOR VARIOUS CONTROL DEVICES ON ROTARY KILNS

	Baghouse	High Efficiency Precipitator	Medium Efficiency Precipitator	22 IWC Scrubber	15 IWC Scrubber	9 IWC Scrubber	Gravel Bed Filter
125 TPD Kiln							
Investment Capital	$339,000	$475,000	$396,000	$312,000	$296,000	$268,300	$777,000
Total Annualized Costs	99,500	112,600	92,700	151,300	136,300	118,600	161,200
a) Maintenance, Labor	20,000	8,800	3,800	15,600	14,800	13,400	7,800
b) Power	6,000	7,900	5,500	37,600	26,700	16,000	10,000
c) Dust Disposal	21,100	21,100	21,100	34,800	34,800	34,800	21,100
d) Capital Charges	38,800	55,800	46,500	50,800	48,200	43,700	91,300
e) Taxes, Insurance, Administrative Costs	13,600	19,000	15,800	12,500	11,800	10,700	31,000
250 TPD Kiln							
Investment Capital	$623,000	$640,000	$567,000	$422,000	$400,000	$362,600	$935,000
Total Annualized Costs	192,200	170,800	148,500	248,700	224,300	193,300	218,700
a) Maintenance, Labor	39,900	12,000	6,000	21,100	20,000	18,100	9,300
b) Power	12,000	15,800	11,000	72,300	53,500	32,000	20,000
c) Dust Disposal	42,200	42,200	42,200	69,700	69,700	69,700	42,200
d) Capital Charges	73,200	75,200	66,600	68,700	65,100	59,000	109,800
e) Taxes, Insurance, Administrative Costs	24,900	25,600	22,700	16,900	16,000	14,500	37,400
500 TPD Kiln							
Investment Capital	$928,000	$869,000	$806,000	$685,300	$648,800	$588,100	$1,103,000
Total Annualized Costs	334,500	268,800	240,900	463,100	410,200	352,000	309,100
a) Maintenance, Labor	80,000	16,000	7,600	34,300	32,400	29,400	11,000
b) Power	24,000	31,600	22,000	150,500	106,900	64,000	40,000
c) Dust Disposal	84,400	84,400	84,400	139,400	139,400	139,400	84,400
d) Capital Charges	109,000	102,000	94,700	111,500	105,600	95,700	129,600
e) Taxes, Insurance	37,100	34,800	32,200	27,400	25,900	23,500	44,100

This explains why baghouses appear to be relatively less expensive on the 125 ton-per-day unit than other devices, for example precipitators. Three levels of scrubbing efficiency are represented in the 9 inch, 15 inch and 22 inch pressure drop scrubbers. Two levels of electrical precipitation are represented.

The parameters used to calculate energy costs and solid disposal costs are summarized in Table 7-9. These parameters are also presented in Chapter 6.

The centrifugal wet fan scrubber required on the hydrator is estimated to cost $10,000 in capital. Normally, the hydrator will have simple water sprays for capturing the valuable product. Hence, items such as ductwork, piping, and pumps that return the collected materials to the hydrator are parts of the process system. The annualized costs for the packed scrubber are approximately $3000 and amount to only 4 cents per ton hydrate, which is considered negligible.

7.2.1.4 Analysis of Control Alternatives

The purpose of this section is to analyze the cost of each of the alternative emission control systems presented in Chapter 6 and to determine the incremental costs of these alternatives over requirements with state regulations. A summary of these alternative emission control systems is presented in Table 7-10. The typical state regulation can be met with use of the 9-inch pressure drop scrubber or the medium efficiency electrostatic precipitator. The latter is chosen as the baseline for the cost analysis because of its lower annualized costs, as shown in Table 7-8.

TABLE 7-9. ENGINEERING PARAMETERS FOR ESTIMATING OPERATING COSTS

Control Device	Energy Consumption kilowatt-hours per ton Lime	Solids Disposal Pounds per ton Lime
Baghouse	4.84	340
High Efficiency Precipitator	6.38	340
Medium Efficiency Precipitator	4.42	340
22 IWC Scrubber	30.4	422
15 IWC Scrubber	21.6	421
9 IWC Scrubber	12.9	421
Gravel Bed Filter	8.1	340

TABLE 7-10. SUMMARY OF ALTERNATIVE EMISSION CONTROL SYSTEMS

Alternative	Emission Control Systems
A-1	Baghouse, High Efficiency Precipitator, or 22 IWC Scrubber
A-2	Baghouse, Medium Efficiency Precipitator, or 15 IWC Scrubber
B-1	a) Baghouse, High Efficiency Precipitator - Sources with Low Sulfur Fuel Only
	b) 22 IWC Scrubber - Sources with high or low sulfur fuel
B-2	a) Baghouse, Medium Efficiency Precipitator - Sources with Low Sulfur Fuel Only
	b) 15 IWC Scrubber - Sources with high or low sulfur fuel
C	Medium Efficiency Precipitator or 9 IWC Scrubber

A summary of the incremental control costs for each alternative emission control system is presented for the three model plants in Table 7-11. The incremental costs are the measure of costs between the required control device for each alternative emission control system and the lowest cost device, capable of achieving the state regulations in terms of unit cost per ton product. The most representative or the most appropriate of available control devices was selected for each system. In some cases the particular system shows a negative incremental capital requirement despite the positive incremental annualized cost incurred for this system. This is predominant for scrubber systems under alternatives B-1 and B-2. For the A-2, B-2 (low sulfur fuel) system, no costs are incurred because this level is achievable by a control device designed to meet state regulations. No intent has been made to differentiate fuel prices in the analysis.

The results in Table 7-11 indicate that the incremental annualized costs for the A-1 and B-1 (low sulfur fuel) alternative systems are about \$.53 to \$.57 per ton, except for the 125 TPD plant. For the latter, the availability of modular construction and factory assembly are responsible for the lower costs on a baghouse. Higher maintenance and bag replacement are the major factors for the incremental annualized costs. The A-2 and B-2 (low sulfur fuel) alternatives are equivalent to the C alternative.

For the B-1 (high sulfur fuel) alternative, the incremental annualized costs are \$1.21 to \$1.42 per ton for the use of scrubbers. For the B-2 (high sulfur fuel) alternative, these costs are \$0.92 to \$1.06 per ton for scrubbers. Although capital costs for scrubbing systems are less than similar costs for baghouses and precipitators, significant costs in energy consumption and waste disposal more than offset savings in capital charges.

TABLE 7-11. INCREMENTAL CONTROL COSTS FOR ALTERNATIVE EMISSION CONTROL SYSTEMS - NEW SOURCES

	Control Device Selected	125 TPD	250 TPD	500 TPD
A-1, B-1 (Low Sulfur Fuel)				
Incremental Capital ($)	Baghouse	(57,000)	56,000	122,000
Incremental Annualized Costs ($)		6,800	43,400	93,600
Unit Cost, $/T		0.16	0.53	0.57
Unit Cost, % of Price		<1	1.9	2.1
A-2, B-2, (Low Sulfur Fuel)				
Incremental Capital ($)	Medium Efficiency Precipitator	0	0	0
Incremental Annualized Costs ($)		0	0	0
Unit Cost, $/T		0	0	0
Unit Cost, % of Price		0	0	0
B-1 (High Sulfur Fuel)				
Incremental Capital ($)	22 IWC Scrubber	(84,000)	(145,000)	(120,700)
Incremental Annualized Costs ($)		58,600	100,200	222,200
Unit Cost, $/T		1.42	1.21	1.35
Unit Cost, % of Price		5.2	4.4	4.9
B-2, (High Sulfur Fuel)				
Incremental Capital ($)	15 IWC Scrubber	(100,000)	(167,000)	(157,200)
Incremental Annualized Costs ($)		43,600	75,800	169,300
Unit Costs, $/T		1.06	0.92	1.03
Unit Costs, % of Price		3.9	3.3	3.7
C				
Incremental Capital ($)	Medium Efficiency Precipitator	0	0	0
Incremental Annualized Costs ($)		0	0	0
Unit Cost, $/T		0	0	0
Unit cost, % of Price		0	0	0

7.2.2 Modified/Reconstructed Facilities

7.2.2.1 Introduction

As discussed in Chapter 5, the primary alteration foreseen during the 1978 to 1987 period at many existing lime plants that might be considered a modification will be conversion of gas or oil-fired kilns to coal. A kiln undergoing such a change in operations ordinarily could utilize the same control system and still comply with state standards. However, under the modification provisions associated with standards of performance, the kiln may become subject to compliance with these standards. If so, the kiln would have to upgrade, or replace in entirety, the control system.

In this section, cost information is presented for lime plants if this alternation is considered a modification. The aspects of the regulation of both particulate and sulfur dioxide emissions will be analyzed.

7.2.2.2 Control Costs for Modified Sources

The basic control costs were developed in Section 7.2.1 The same information can be used to analyze the economic impact on individual plants if fuel switching is considered a modification.

The cost analysis is structured for four model plant cases. (See Table 7-12). The first case is for a recently built 500 TPD plant with a baghouse; the second, a relatively old plant (125 TPD) with a cyclone device; the third, a 500 TPD plant with an electrostatic precipitator; and the fourth, a 500 TPD plant with a scrubber. All of these plants are assumed to be meeting state regulations. Each of these cases is analyzed for the cost impact under each-of the alternative emission control systems discussed in Section 7.2.1.

TABLE 7-12. INCREMENTAL CONTROL COSTS FOR ALTERNATIVE EMISSION CONTROL SYSTEMS MODIFIED SOURCES

Kiln Production Rate Existing Controls	Case 1 500 TPD Baghouse	Case 2 125 TPD Cyclone	Case 3 500 TPD Precipitator	Case 4 500 TPD Scrubber
A-1, B-1 (Low Sulfur Fuel				
Incremental Capital ($)	0	440,000	0	187,000
Incremental Annualized Cost ($)	0	115,000	0	134,000
Unit Cost, $/T	0	2.79	0	0.81
Unit Cost, % of Price	0	10.2	0	3.0
A-2, B-2 (Low Sulfur Fuel)				
Incremental Capital ($)	0	440,000	0	178,000
Incremental Annualized Costs ($)	0	115,000	0	81,500
Unit Cost, $/T	0	2.79	0	0.49
Unit Cost, % of Price	0	10.2	0	1.8
B-1 (High Sulfur Fuel)				
Incremental Capital ($)	890,000	406,000	890,000	270,000
Incremental Annualized Costs ($)	3T6,000	164,000	391,000	146,000
Unit Cost, $/T	1.92	3.98	2.37	0.88
Unit Cost, % of Price	7.0	14.5	8.6	3.2
B-2 (High Sulfur Fuel)				
Incremental Capital ($)	840,000	385,000	840,000	240,000
Incremental Annualized Costs ($)	261,000	148,000	336,000	94,400
Unit Cost, $/T	1.58	3.59	2.04	0.57
Unit Cost, % of Price	5.7	13.1	7.4	2.1

The type of alterations that could occur with a fuel conversion would include fuel switching to a low or high sulfur coal and possibly the addition of a stone pre-heater. Consistent with the discussion in Chapter 5, plants with existing cyclones or low energy scrubbers are assumed to require upgrading these devices for a potential increase in either particulate or sulfur dioxide emissions. Plants with existing baghouses or precipitators are assumed to upgrade for sulfur dioxide emissions only.

Control costs for the Case 2 plant reflect the addition of a baghouse for the A-1 and A-2 alternatives, as well as the B-1 and B-2 alternatives for low sulfur fuel applications. The control costs for the case 2 plant under the B-1 and B-2 alternatives with high sulfur fuel are based on the addition of a complete 22 IWC scrubber system. The costs for cases 1 and 3 for the B-1 and B-2 alternatives with high sulfur fuel are determined in the same fashion as case 2. The case 4 plant costs estimates include only the upgrading of the venturi-separator section, the fan, motor and starter. The main difference in case 4 plant costs shown in Table 7-12 for the various alternatives reflect the use of corrosion resistant materials in the venturi and the fan for high sulfur fuel applications.

An assumed retrofit penalty of 30 percent was included in the cost estimates for the modified sources. This means that a retrofitted system on an existing source would require 30 percent more capital than for a brand new source. The 30 percent factor is a reasonable engineering judgment for inclusion of such items as the removal of existing systems, additional engineering to design the retrofit system, and minor changes in the offsite utilities, such as electrical distribution.

The incremental annualized costs shown in Table 7-12 are in addition to the costs incurred by existing plants to comply with state regulations.

The incremental annualized costs include capital charges for the retrofit capital, and cost increases incurred for power, disposal, maintenance, taxes, and insurance.

According to the results in Table 7-12, the most expensive situations occur for the modified sources involved with switching from a low sulfur to high sulfur fuel. For an existing 500 TPD plant, with a baghouse the annualized costs for the B-1 alternative are $1.92 per ton and $1.58 per ton for the B-2 alternative. For an existing 500 TPD plant with a precipitator, these annualized costs increase to $2.37 and $2.04 per ton, respectively. For the existing 500 TPD with a scrubber, annualized costs for upgrading the scrubber are $0.88 and $0.57 per ton, respectively.

For other modified sources that are concerned only with increase in particulates, annualized costs are significant for existing sources with low efficiency controls. For example, a 125 TPD plant with a cyclone would incur a cost of $2.79 per ton for a baghouse for either A-1 or A-2 alternative. The 500 TPD plant with a 9 IWC scrubber in compliance with a state regulation would incur costs of $0.81 per ton for the A-1 alternative and $0.49 for the A-2 alternative to upgrade the scrubber. Existing sources with baghouses or precipitators are assumed not to incur any costs specifically for particulate controls.

7.3 OTHER COST CONSIDERATIONS

The scope of this analysis included the development of standards for air emissions from lime kilns. In addition, the lime industry is anticipated to be affected by new source performance standards for the crushed stone and aggregate industry, which include the preparation of limestone rock. The costs of controls for this process step have not been analyzed in this chapter.

In addition to the air controls for rock preparation, the lime industry must also comply with EPA's water effluent guidelines for existing facilities and new source performance standards for new facilities. For both, the limitation is a zero discharge of contaminants into streams. The only source of water effluents from lime plants is derived from water used in scrubbers to control air particulates emissions.

The control technology required to achieve this limitation for water effluents is a closed-loop water system. Such a system can be achieved by a well-constructed, holding basin (pond, lagoon) sufficient in size to handle water overflows during periods of heavy rainfall. The alternative control system is a mechanical clarifier-filtration system. The latter would be preferred where space limitation, terrain, or soil conditions would render construction of a holding basin prohibitively expensive or unfeasible. An attempt was made to recognize these water costs in Section 7.2 by inclusion of ponding in the scrubber system cases.

Capital and operating costs for continuous monitoring of visible emissions and sulfur dioxide are reported in Appendix D. The magnitude of these costs is small in relation to the incremental control costs as detailed in Section 7.2. There is no discernible impact that can be foreseen with the requirement of monitoring either or both visible emissions and sulfur dioxide.

As far as OSHA costs are concerned, EPA is unaware of any major problems encountered in the health and safety aspects of lime plant operations.

7.4 ECONOMIC IMPACT OF ALTERNATIVE EMISSION CONTROL SYSTEMS FOR NEW AND MODIFIED SOURCES

7.4.1 Introduction

The purpose of this section is to discuss the economic impact of the incremental control costs for each alternative emission control system identified in Chapter 6 in terms of industry growth, product prices, and balance of trade considerations. Capital requirements for incremental controls are also discussed.

The following assumptions are used to analyze the economic impacts of emission control alternative systems on new and modified sources. The first assumption is that competition among lime producers will limit unilateral attempts to increase prices to pay for incremental control costs. This assumption is more critical for commercial lime producers than for captive plants, which probably can pass on the increased costs. Consequently, control costs will be addressed for two situations--one in the absence of a price increase, the other in the absence of a change in profitability. The second assumption is that product differentiation characterized by more than a single price for lime is not a major factor in the industry. Although there is reason to believe that product quality requirements may command a higher price for metallurgical lime than for, let us say, sewage treatment lime, not enough information is available to substantiate a schedule of multiple prices. As a result, only a single price will be used for the product in the analysis.

As indicated in Section 7.1 there is a continuing trend in lime industry toward larger plants. This is partially due to the economies of scale associated with the mechanization of the industry, and perhaps also due to the economies of scale associated with environmental controls. Besides the environmental control requirements specifically addressed in this document, the lime industry has recently faced another important shock: the energy crisis. Dramatic recent increase in prices of all fuels and diminished availability of natural gas have forced many plants in the industry to convert to coal-burning facilities, utilizing stone preheaters in many cases. This includes many existing plants which have retrofitted their kilns to provide a coal-firing capability. The conversion of a plant to utilize a switch in fuels is the type of plant alteration that will be analyzed as a modified source.

7.4.2 New Sources

7.4.2.1 Profitability Impact Analysis

In this section, the impact of incremental costs associated with each alternative emission control system is measured in terms of a new plant's profitability. The incremental annualized control costs from Section 7.2 are assimilated into the plant's cost structure to calculate profit after tax (PAT) on a unit ton basis without a price increase. Similarly, price increases necessary to maintain historical returns are calculated. The PAT is determined by assuming a 6 percent profit margin (after-tax) on sales. Profit margins for this industry have been reported to range from 4 to 6 percent sales.(30) A sales estimate for a model plant is taken as $27.50 per ton, which is the approximate reported Bureau of Mines price for lime in 1975.(31) The tax rate on income is assumed to be 50 percent. The calculated PAT, which is $1.65 per ton, is then related to the capital investment for a baseline grass roots plant. Such a plant is assumed to be meeting state standards for control of air emissions. This plant should cost about $35 per ton annual capacity.(32) The derived PAT of $1.65 per ton yields a after-tax ROI of 4.8 percent. The percent declines in ROI and required price increases to maintain baseline ROI are then calculated for each alternative emission control system. See Table 7-13 for results.

Interpretation of the results leads to the conclusion that none of the alternative emission control systems preclude new plant investment. The price increase required to maintain ROI for alternative A-1 is 2.6 percent; and for alternative A-2, no increase in price is required. In the judgment of EPA, price increases on the order of 3 percent are considered as having minimal adverse impact. A new source, in either the commercial or captive sectors, can probably offset increased control cost of this magnitude by achieving economies of scale in building a larger plant. Furthermore, for most captive plants, such price increases would be much smaller in terms of the price of the end product, such as steel, copper, or magnesium.

Table 7-13. PROFITABILITY IMPACT ANALYSIS FOR ALTERNATIVE CONTROL SYSTEMS ON 500 TPD PLANT/NEW SOURCES
(All values in $ per ton unless stated otherwise)

	State Standard (c)	A-1	A-2	B-1	B-2
Sales	27.50	27.50	27.50	27.50	27.50
Baseline Production Costs	22.74	22.74	22.74	22.74	22.74
Control Costs	1.46	2.03	1.46	2.81	2.49
Profit Before Tax	3.30	2.73	3.30	1.95	2.27
Profit After Tax	1.65	1.36	1.65	0.98	1.14
Total Plant Capital	34.40	35.60	34.40	34.20	33.90
PAT ÷ Capital (ROI), %	4.8	3.8	4.8	2.9	3.4
Decline in ROI, %	-	20	-	40	29
Price to Maintain ROI	27.50	28.21	27.50	28.83	28.50
Price Increase to Maintain ROI, %	-	2.6	0	4.8	3.6

Considering alternatives B-1 and B-2, kilns burning low sulfur coal would resemble plants meeting particulate standards under alternative A-1 and A-2. Only plants burning high sulfur coal would appear to incur a somewhat higher impact under alternatives B-1 and B-2. The price increase under alternative B-1 is 4.8 percent compared with the 2.6 percent under alternative A-1. The less stringent alternative involving a sulfur limitation, B-2, requires a price increase of 3.6 percent versus no increase for the corresponding alternative A-2.

The relative differences in impacts between the A and B alternatives are analytical results derived without any consideration of fuel price differences between low and high sulfur fuels. According to industry opinion,(33) fuel use trends are toward metallurgical (low sulfur) coal for the purpose of producing sulfur-free lime. High sulfur fuels cannot be considered then as a substitute fuel for technical reasons in such cases. Where high sulfur fuels can be burned for some applications, the new source probably will find little difficulty in handling the relatively higher costs for alternatives B-1 and B-2. In those lime markets where sulfur content of lime is not critical, the high sulfur fuel user, despite relatively higher control costs, can probably compete with low sulfur users from the standpoint of lower fuel costs.

7.4.2.2 Capital Requirements and Availability

This portion of the economic analysis addresses itself to the impact of the new source performance upon the capital requirements and financial resources of the industry. The question arises whether the increased capital requirement for meeting standards of performance will pose any problem for raising capital in the industry.

Since the trend in plant construction will be toward 500 TPD units, incremental capital requirements for a 500 TPD unit have been derived for each of the alternative emission control systems. The baseline plant is assumed to install a low efficiency precipitator to meet state regulations. The capital for such a plant including the precipitator, is $5,798,000, which corresponds to the $34.40 per ton annual capacity shown in Table 7-13. Using this baseline, the incremental capital requirements are derived for each of the alternatives--A-1, A-2, B-1, and B-2. The calculations are shown in Table 7-14. Only the A-1 alternative shows any additional capital requirement over the baseline case, a 2.1 percent increase. Capital requirements for the B-1 and B-2 alternatives are less than the baseline case. Judging from the results shown in Table 7-14, there would not appear to be any problem toward raising additional capital for any of the alternative emission control systems.

7.4.3 Modified Sources

7.4.3.1 Profitability Impact Analysis

Just as for new sources, the impact of incremental costs associated with each alternative emission control system is measured in terms of the impact upon the profitability of new plant investment. The type of investment to be analyzed in this section is that associated with conversion of a gas-fired kiln to coal. This type of fuel conversion appears to be the only plant alteration incurring a significant cost impact with the alternative emission control system under investigation, that is, alternatives B-1 and B-2 limiting sulfur.

Table 7-14. INCREASE IN CAPITAL REQUIREMENTS FOR ALTERNATIVE EMISSION CONTROL SYSTEMS NEW LIME KILNS

Base Case: 500 TPD Plant with low efficiency precipitator (System C)

	A-1	A-2	B-1	B-2	C
Total Plant Capital ($1000)	5798	5676	5555	5519	5676
Incremental Plant Capital ($1000)	122	0	(121)	(157)	--
Increase, %	2.1	0	(2.1)	(2.8)	--

The profit impact analysis is based on a 500 TPD plant that is assumed to undergo a marginal investment of $1.5 million for converting a gas-fired facility to coal. This estimate represents the installed costs for coal handling and preparation facilities, as well as burner changes.(34) The plant undergoing this modification is assumed to continue the use of the same control system for the kiln, in the absence of new source performance standards, without additional costs. The marginal return for this investment is calculated to be an 18.2 percent profit after tax (PAT). This is derived from the following assumptions: (1) a sales price of $27.50, (2) baseline production costs of $24.20, which includes emission controls to meet state regulations, (3) a tax rate of 50 percent, and (4) historical plant investment is treated as a sunk cost. These are the same assumptions that would confront many existing sources in the industry today faced with a cut-off of a fuel supply. No attempt has been made to factor in higher fuel prices which would necessitate prediction of higher lime prices.

The incremental annualized costs for alternatives A-1, A-2, B-1, and B-2 from Section 7.2 are assimilated into the cost structure of the model plant to determine the impact on PAT and the required price increases to maintain the expected 18.2 percent return. Two types of model plant situations are analyzed--one existing plant with a baghouse and another with a 9 IWC scrubber. The resultant declines in profit and expected price increases (sufficient to maintain profitability) are shown in Table 7-15.

Table 7-15. PROFITABILITY IMPACT ANALYSIS FOR ALTERNATIVE CONTROL SYSTEMS ON 500 TPD PLANT/MODIFIED SOURCES
(All values stated in $ per ton unless stated otherwise)

	Base Case	A-1		A-2		B-1		B-2	
Existing Controls	Baghouse or Scrubber	Baghouse	9 IWC Scrubber	Baghouse	9 IWC Scrubber	Baghouse	9 IWC Scrubber	Baghouse	9 IWC Scrubber
Additional Controls	------	None	Upgrade Scrubber (22 IWC)	None	Upgrade Scrubber (15IWC)	22IWC Scrubber	Upgrade Scrubber (22IWC)	22IWC Scrubber	Upgrade Scrubber (15IWC)
Sales	27.50	27.50	27.50	27.50	27.50	27.50	27.50	27.50	27.50
Baseline Production Costs(1)	24.20	24.20	24.20	24.20	24.20	24.20	24.20	24.20	24.20
Incremental Control Costs	--	--	0.81	--	0.49	1.92	0.88	1.58	0.57
Profit Before Tax	3.30	3.30	2.49	3.30	2.81	1.38	2.42	1.72	2.73
Profit After Tax (PAT)	1.65	1.65	1.25	1.65	1.41	0.69	1.21	0.86	1.37
Marginal Plant Investment	9.09(2)	9.09	10.22	9.09	10.17	14.48	10.73	14.18	10.54
Pat ÷ Capital (ROI), %	18.2	18.2	12.2	18.2	13.9	4.8	11.3	6.1	13.0
Decline in ROI, %	--	--	33	--	24	74	38	66	29
Price to Maintain ROI	27.50	27.50	28.73	27.50	28.39	31.39	28.99	30.94	28.61
Price Increase to Maintain ROI, %	--	--	4.5	--	3.2	14.1	5.4	12.5	4.0

(1) Production costs include environmental controls to meet state regulations.
(2) Based on marginal investment of $1.5 MM.

Interpretation of the results leads to the conclusion that the alternatives B-1 and B-2 would most probably preclude the marginal investment for existing plants with baghouses. The decline in ROI under B-1 is 74 percent; for B-2, 66 percent. Required price increases are 14.1 percent and 12.5 percent, respectively. In the judgment of EPA, price increases of this magnitude are sufficient to preclude investment.

For plants presently using scrubbers, the declines in ROI are 38 percent for the B-1 alternative, and 29 percent for the B-2 alternative. Price increases are 5.4 percent and 4.0 percent, respectively. In the judgment of EPA, plants presently using scrubbers would not necessarily be deterred from undergoing the marginal investment. From the standpoint of ranking various investments, modification of an existing plant still offers a higher return than for a new source. The returns are approximately 12 percent (after tax) for both B-1 and B-2 on the modified source versus approximately the 3.4 to 4 percent (after tax) for B-1 and B-2 on new sources. Within this context, it cannot be concluded that plants with scrubbers would shutdown.

For the A-1 and A-2 alternatives, the results in Table 7-15 indicate declines in ROI of 33 percent and 24 percent, respectively for modified kilns that may have to upgrade scrubbers for increased particulates. Price increases are 4.5 percent and 3.2 percent, respectively. In the judgment of EPA, these impacts are not of sufficient magnitude to preclude investment. Existing kilns with baghouses prior to modification are not considered to incur any adverse impact.

7.4.3.2 Capital Requirements

Based on the assumption of conversion to coal, the capital for modifying an existing plant (500 TPD) is \$1,500,000.(35) Using this estimate as a baseline, the incremental capital requirements are determined for the cases analyzed in the profit impact analysis. The results are shown in Table 7-16.

Of all four alternatives, the B-1 and B-2 alternatives stand out as the most restrictive, in particular for plants with baghouses (or precipitators). The existing plant with a baghouse would have to incur an additional 59 percent capital for B-1 and 56 percent for B-2. Plants with scrubbers that would have to upgrade these scrubbers incur a capital increase in the range of 12 to 18 percent, depending upon the alternative. Lastly, plants with baghouses (or precipitators) would not have to incur any capital requirements if increased particulates are the only concern.

The conclusions drawn from Section 7.4.3.1 on the profitability analysis would apply here. For a sulfur limitation, plants with baghouses most probably cannot afford the modification; plants with scrubbers probably can afford to modify.

7.4.3.3 Impact on the Industry

From the previous discussion on profitability and capital requirements, it is clear that sulfur limitation under new source performance standards would have a major adverse impact on some plants switching to high sulfur coal. An analysis of the impact in the industry has to consider the following questions:

(1) How many plants within the industry do not have coal firing capability?

(2) How many of these would likely switch to coal?

Table 7-16. INCREASE IN CAPITAL REQUIREMENTS FOR EACH ALTERNATIVE EMISSION CONTROL SYSTEM/MODIFIED LIME KILNS

Base Case: 500 TPD Plant; existing control can be baghouse or 9IWC Scrubber

	Base Case	A-1		A-2		B-1		B-2	
Existing Controls	Baghouse or Scrubber	Baghouse	9IWC Scrubber	Baghouse	9IWC Scrubber	Baghouse	9IWC Scrubber	Baghouse	9IWC Scrubber
Additional Controls	-------	None	Upgrade Scrubber (22IWC)	None	Upgrade Scrubber (15IWC)	22IWC Scrubber	Upgrade Scrubber (22IWC)	22IWC Scrubber	Upgrade Scrubber (15IWC)
Marginal Plant Investment ($1000)	1500	1500	1687	1500	1678	2390	1770	2340	1740
Incremental Control Investment ($1000)	--	0	187	0	178	890	270	840	240
Increase, %	--	0	12	0	12	59	18	56	16

(3) For those plants that would switch to coal, how many would use high sulfur coal?

Based on a survey of major fuel burning installations by the Federal Energy Administration,(36) some 43 of 47 kilns owned by 21 responding plants have reported to have coal firing capability. The scope of coverage includes plants with a heat input greater than 100 million BTU per hour. The scope of the survey is the SIC 3274 sector. An analysis of fuel use by the respondents was conducted to determine the coverage of the industry by the FEA survey. The results are shown in Table 7-17. According to the Table, the fuel use by the respondents was 60 percent of the total fossil fuel consumption by the SIC 3274 sector. The respondents in the FEA survey burned 77 percent of the coal and 32 percent of the gas consumed by the SIC 3274 sector. These data show that conversion to coal is nearly complete for large users, and perhaps to a great extent for all kilns that could viably burn coal. This would include potentially all kilns with output greater than 250 TPD, according to a designer of lime plant technology.(37) A conclusion based on interpretation of the FEA survey is that approximately 90 percent of large plants presently have coal firing capability. Of the remaining 10 percent, most of these would shift to low sulfur, metallurgical grade coal. This would be consistent with previous industry trends. Consequently, the impact of the B-1 and B-2 alternatives is expected to be small on the industry.

As far as small plants, those producing less than 250 TPD, they will probably use some combination of natural gas, synthetic gas, distillate, or crude oil. None of these fuels are likely to contribute to an increase in sulfur emissions (or particulates) from a fuel switch away from natural

Table 7-17 SUMMARY OF 1974 FOSSIL FUEL ANALYSIS FOR SIC 3274
(Energy units stated in quadrillion BTU equivalents)

	Column A	Column B	Column C
	SIC 3274[2]	FEA Survey[3]	FEA Coverage, % (Column B ÷ Column A)
Fuel Use, Type[1]			
a) Coal	46.8	36.0	77
b) Natural Gas	27.0	8.7	32
c) Fuel Oil	1.0	--	--
TOTAL	74.8	44.7	60

(1) Energy equivalents based on the following: 1 ton of coal = 24 million BTU's; 1 barrel oil = 6 million BTU's; 1 Ft^3 natural gas = 1000 BTU's

(2) Source: Annual Survey of Manufacturers, Department of Commerce

(3) Source: Federal Energy Administration Survey under Energy Supply and Environmental Coordination Act, 1975.

gas. Consequently, no impact from new source performance standards is foreseen for these plants.

7.4.4 Summary

The conclusions of the economic impact analysis are stated as follows. The market for lime is expected to be healthy with an annual compound growth rate in consumer demand projected to be 5 percent. Some 8 to 10 new kilns and 1 to 2 new hydrators are projected to be installed each year for the next ten years. Most modifications for the next ten years will likely be kilns switching from gas to oil. Conversion from gas to coal has been occurring for the past few years and seems nearly complete for the industry.

The cost impact of the A-1 and B-1 alternatives will be 2.6 percent in terms of a price increase (to maintain ROI) for most new kilns, which will be burning low sulfur coal. Similarly, price increase to maintain ROI for B-1 and B-2 is 4.8 percent and 3.6 percent, respectively, for high sulfur fuel burning new kilns. However, there is not expected to be any significant adverse impact for these sources in the judgment of EPA.

The capital requirements are expected to be minimal for new sources for all proposed alternatives. The most stringent alternative, A-1, would require an increase in capital of 2.1 percent. In the judgment of EPA, this is considered to be reasonable.

The cost impact and capital requirements were analyzed for various types of modified sources. For certain modifications, such as plants switching from gas to high sulfur coal, the economic impact could be adverse. However, there are very few modifications of this nature expected to occur. No economic impact is foreseen to occur for the plants switching to oil; such modifications are not expected to incur any incremental costs associated with the proposed alternatives.

Lastly, the economic impact on hydrators is expected to be very small. The cost impact for these sources is very small, on the order of a tenth of 1 percent.

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8. RATIONALE FOR THE PROPOSED STANDARDS

8.1 SELECTION OF SOURCE FOR CONTROL

The lime manufacturing industry has been identified as a significant nationwide source of air pollutant emissions which cause or contribute to the endangerment of the public health or welfare. Emissions from lime plants include particulate matter, sulfur dioxide (SO_2), carbon monoxide (CO), and nitrogen oxides (NO_x). In 1975 there were 170 lime plants operating in 40 states producing approximately 20 teragrams (22 million tons) of lime per year. Since 1930, the lime industry has experienced a growth rate of about 5 percent per year. This rate is projected to continue through 1985. The typical lime manufacturing plant used in this document to base the impacts of the proposed standards on is one that produces 454 megagrams (500 tons) per day of lime from 907 megagrams (1000 tons) of limestone feed in the rotary kiln. About 10 percent of the lime produced is further treated by hydration in a lime hydrator. The typical lime hydrator produces 227 megagrams (250 tons) per day of hydrated lime from 182 megagrams (200 tons) of lime feed. The typical state standards for lime plants require control of particulate emissions from lime kilns and hydrators to 0.5 kilogram per megagram (1.0 pound per ton) of feed. The typical state standards also require control of SO_2 from lime kilns to 1.0 kilogram per megagram (2.0 pounds per ton) of stone feed.

A lime manufacturing plant conforming to the level of the typical state control standards and operating an average of 330 days per year would emit about 150 megagrams (165 tons) per year of particulate matter from the lime kiln and 30 megagrams (33 tons) per year from the hydrator. If the kiln burns coal which contains a low sulfur content, the emissions of SO_2 are about 150 megagrams (165 tons) per year. If high sulfur content, about three percent, coal is burned, SO_2 emissions are about 300 megagrams (330 tons) per year from the kiln.

In a study[1] performed for EPA by Argonne National Laboratory in 1975, the lime industry ranked seventh on a list of the 56 largest particulate source categories in the U.S. The list contains all of the stationary sources of particulate matter for which control technology exists which is capable of reducing emissions to a level below that required by state standards and for which no significant economic impacts would be encountered as a result of the application of such control technology. In addition, the study ranked the lime industry fifth on a list of seven domestic SO_2 source categories.

A second study,[2] performed for EPA in 1975 by The Research Corporation of New England (TRC), ranked the lime industry 13th on a list of 112 stationary source categories which emit particulate matter. In this study, lime plants were also placed 21st on a list of 41 stationary sources emitting SO_2.

In addition, in the prevention of significant deterioration regulations published in the Federal Register on December 5, 1974 (39 FR 42510), lime plants were included on the list of industrial processes which are sources of particulate matter and SO_2 that are capable of contributing to the deterioration of existing air quality. Under the provisions of these regulations, construction of new lime plants or modification of existing plants can be denied unless the Administrator determines that the operation of the facility will not cause a violation of the allowable air quality increments which are applicable to the area affected by the emissions.

The lime manufacturing industry which would be covered by the proposed standards includes both commercial and captive operations. Presently about 22 percent of the lime used in this country is produced by captive manufacturers for whom the manufacture of lime is an intermediate step. Examples of these types of manufacturers are the steel industry, for use with the basic oxygen furnace (BOF), and the sugar beet processing industry, for use in removing impurities from the crude sugar juices.

The proposed standards would not apply to lime kilns that process wet lime sludges, such as in kraft pulp mills. Standards of performance covering emissions from these sources were proposed in the Federal Register on September 24, 1976 (41 FR 42012).

Based on the large number of existing lime plants, the current and projected growth rate in the industry, the wide range of plant location across the United States, and the reduction impacts on mass emissions that are achievable, the source category of lime manufacturing plants has been selected for control through the development of standards of performance.

8.2 SELECTION OF POLLUTANTS AND AFFECTED FACILITIES

8.2.1 Pollutants

Emissions from lime plants include particulate matter, sulfur dioxide (SO_2), carbon monoxide (CO), and nitrogen oxides (NO_x). The lime kiln has been identified as an emitter of all four pollutants. The hydrator is a source of particulate matter only. In addition, fugitive emissions of particulate matter may occur from transfer points, screens, and loading operations.

Emission tests on presently operating sources have indicated that NO_x concentrations are normally in the range of 200 ppm in the exit gas from the particulate control device. This is equivalent to an NO_x emission rate of about 0.45 pound of NO_x per million Btu heat input. Assuming adverse meteorological conditions and the occurrence of aerodynamic downwash, an ambient air quality dispersion model of NO_x emissions from the typical lime kiln controlled to level of a typical state standard shows a maximum concentration of about 10 $\mu g/m^3$. This is 10 percent of the EPA primary and secondary ambient air quality standard of 100 $\mu g/m^3$ (.05 ppm) annual arithemtic mean for NO_x. Since the NO_x emission reduction that can be achieved through combustion modification or other control techniques has not been demonstrated for lime kilns, NO_x emissions from lime kilns have not been selected for control.

Emission tests on the exit gas from the particulate control device indicate that CO emissions from lime kilns are normally in the range of 100 ppm. Assuming adverse meteorological conditions and the occurrence of aerodynamic downwash, an ambient air quality dispersion model of CO emissions from a typical well controlled kiln shows a maximum concentration of about 30 $\mu g/m^3$ (eight-hour average). This is less than 1.0 percent of the

EPA primary ambient air quality standard of 10,000 $\mu g/m^3$ (9 ppm) maximum eight-hour average, not to be exceeded more than once per year, and the secondary standard of 40,000 $\mu g/m^3$ (35 ppm) maximum one-hour average, not to be exceeded more than once per year. The most effective control method that has been demonstrated for reducing CO emissions from rotary lime kilns is incineration of the off-gases. The use of this technique would cause a severe fuel penalty with very little environmental benefit. Consequently, CO emissions from lime plants have not been selected for control by standards of performance.

Emissions of particulate matter from the model 907-megagrams-per-day (1000-tons-per-day) lime kiln, controlled to meet a typical state standard, amount to about 19 kg per hour (42 lb per hour). The maximum ground level concentration under adverse meteorological conditions resulting in aerodynamic downwash for a dry control system (e.g. a baghouse) is about 26 $\mu g/m^3$ (24-hour average). When a scrubber is used to control emissions, the maximum ground-level concentration increases to about 42 $\mu g/m^3$ (24-hour average) because the cooler exhaust gases cause poor dispersion characteristics. Under conditions of no downwash from the stack, the maximum particulate concentrations from a dry control system and from a scrubber are approximately 3 $\mu g/m^3$ and 6 $\mu g/m^3$, respectively.

Particulate emissions controlled to meet the level of the proposed standard, which requires an incremental reduction of 70 percent more than a typical state standard, result in corresponding reductions in the load to the ambient air particulate concentration. The 24-hour average concentration, when the stack is designed to prevent aerodynamic downwash and produce optimum dispersion, is less than 2 $\mu g/m^3$, when either a dry system or a scrubber is used.

Particulate matter emissions from the hydrator controlled to meet a typical state standard amount to about 6.4 kilograms (14 pounds) per hour. This emission rate assumes that the lime hydrator is operated about 14 hours per day to process 182 megagrams (200 tons) of lime into 227 megagrams (250 tons) of hydrated lime. Almost all existing hydrators are controlled by scrubbers of varying efficiencies. With the application of the best type of wet fan scrubbers, the particulate emissions from hydrators could be reduced by 85 percent compared to a typical state standard of 0.5 kg/Mg.

Since significant reductions in the mass emissions of particulate matter from lime kilns and hydrators are possible, standards of control of these emissions are being proposed. The levels of the proposed emission limits are discussed in section 8.5.

The lime kiln is the only source of SO_2 emissions at a lime manufacturing plant, excluding any power generating facilities that may also be present. The SO_2 is principally due to the presence of sulfur compounds in the fuel used to heat the kiln. Emissions of SO_2 from the 907 Mg/d (1000 tpd) model plant controlled to the level of a typical state standard, emitting about 37 kilograms (82 pounds) per hour when using 3 percent sulfur coal, will cause a maximum ground level concentration of about 85 $\mu g/m^3$ (24-hour average) under adverse meteorological conditions and aerodynamic downwash. Therefore, emissions of SO_2 from lime plants under the most adverse conditions would account for about 25 percent of the 24-hour national ambient air quality standard of 365 $\mu g/m^3$.

As discussed in chapters 3 and 4, a significant reduction in SO_2 emissions is achieved by the presence of the lime dust in the kiln and at the outlet point. The amount of SO_2 removal depends on several factors including the chemical composition of the stone, the temperature in the kiln, the amount of excess oxygen in the kiln, and the amount and particle size of the lime dust present in the kiln.[4] When dry control systems such as a baghouse or an ESP are used, about 88 percent of the SO_2 remains in the lime and 12 percent is emitted to the atmosphere. When a scrubber is used, about 6 percent of the SO_2 is emitted to the atmosphere. These values are based on the results of the EPA source tests, presented in Appendix C.

An analysis of the available control alternatives yields the following comparisons:

(1) Compared to baghouses, scrubbers would reduce SO_2 emissions from a model 907 Mg per day (1000 tpd) kiln by 150 Mg per year (165 tons per year). A scrubber with a pressure drop of 22 IWC requires about six times more energy to operate than a baghouse and is equivalent to a total plant energy increase of 4 percent. If this energy is produced in a coal-fired power plant, an additional 23 tons of SO_2 per year would be produced, assuming that the power plant conforms to the standard of performance of 0.52 gram per megajoule heat input (1.2 pounds of SO_2 per million Btu's heat input). The power source would also produce additional emissions of particulate matter and nitrogen oxides while generating the additional energy.

(2) The temperature of the stack gas following a scrubber is lower than that following a dry control device. Consequently, the dispersion characteristics of the emissions are not as favorable, and the maximum predicted concentration of SO_2 in the ambient air is only slightly less from the scrubber even though the SO_2 emission rate is one-half that of the dry control system. Under conditions of no aerodynamic downwash, there is no predicted difference in the maximum ambient concentrations resulting from the two control systems.

(3) EPA published effluent guidelines for the lime industry on March 21, 1974 (39 FR 9621), which require zero discharge of water. If scrubbers are required on kilns in order to meet an SO_2 standard, existing lime plants could have difficulty in meeting this level.

(4) The capital costs of installing a scrubber are less than for a baghouse. The annualized operating costs, however, are twice as high for a scrubber than for the dry control devices. The costs are presented in Chapter 7.

In summary, an incremental reduction in SO_2 emission rates (94 percent control versus 88 percent) is achievable with scrubbers compared to dry control systems. This reduction, however, would be accomplished with corresponding adverse environmental and economic impacts that do not appear to be reasonable. EPA has therefore determined that requiring a standard of performance for control of SO_2 from lime plants is not justified at this time, and no standard is being proposed.

8.2.2 Affected Facilities

The significant sources of particulate emissions at a lime plant are the lime kiln and the hydrator unit. Additional secondary sources which produce fugitive emissions are product transfer points and screening and loading operations.

There are several types of kiln designs that are currently used by the lime industry in this country. As discussed in chapter 3, the major types are the rotary kiln, the verticle kiln, the rotary hearth kiln, and the fluidized bed kiln. Approximately 90 percent of the lime produced in the U.S. today is calcined in rotary kilns. Virtually all of the new kilns installed in the last two years have been rotary kilns,[4] and this trend is expected to continue in the future. In addition, rotary kilns are the only type of kiln that can utilize coal as fuel and still maintain acceptable product quality. It is expected that as supplies of natural gas and oil become more expensive or unavailable, all new kilns would be rotary lime kilns designed to burn coal.

Of the estimated ten percent of the industry which are non-rotary type kilns, the majority are small operations and do not constitute a significant source of emissions. Since the future need in the industry is to have coal burning capabilities, the current trend is to replace existing kilns with rotary kilns. The facilities that would be affected by the proposed standards would therefore tend to be of the rotary design.

About ten percent of the lime produced in this country is also treated by hydrators and converted to slaked or hydrated lime. Uncontrolled particulate emissions from hydrators may be as high as 545 kilograms (1200 pounds) per hour, a higher emission rate than has been estimated for a typical lime kiln controlled with a cyclone. The typical state standard requires that particulate emissions from a hydrator are controlled by a low efficiency scrubber to attain a level of about 0.5 kg/mg (1.0 lb/ton).

Since the rotary lime kiln and the lime hydrator are both significant sources of particulate matter, they are selected as the affected facilities for which the proposed standards will apply.

The potential points of fugitive particulate emissions at a lime plant are at product transfer points and screening and loading operations. These sources produce an unquantified amount of dust. Although various emission control techniques have been identified which could reduce emissions from these fugitive dust sources, insufficient data concerning the effectiveness of these techniques are available to determine achievable emission reductions. Consequently, these sources are not covered at this time by the proposed standards.

Definition of the Affected Facilities

8.2.2.1 Rotary lime kilns

The rotary lime kiln is the only type of kiln design that is regulated by the proposed standard. Virtually all of the existing and all of the new kilns used in the industry are rotary design. Each kiln operates independently of the other kilns in a lime plant, with no interaction between kilns. Kilns that process lime from a sludge, such as those at kraft pulp mills, are covered by a separate standard. The affected facility is therefore defined as, "a unit with an inclined rotating drum which is used to produce a lime product from limestone by calcination."

8.2.2.2 Hydrator

The hydration process consists of blending the lime with water in a pre-mixer and agitating this mixture to obtain a complete chemical reaction. The hydrator operates as a separate system from the lime kiln and is controlled by its own control devices. At plants where there are multiple hydrators, each operates independently. Therefore, the affected facility is defined as "a unit used to produce a hydrated lime product."

8.3 SELECTION OF THE BEST SYSTEM OF EMISSION REDUCTION CONSIDERING COSTS

The purpose of the proposed standards is to require that the best emission control technology, considering costs, for particulate matter be installed and operated at new and modified lime plants. The affected facilities to be controlled by the standards are rotary lime kilns and the hydrator units. The proposed standards are based on data on emission control systems and methods of process operation received through (1) on-site observations of plant processes and control equipment, (2) consultation with industry representatives and control equipment vendors, (3) emission tests conducted by EPA on presently operating rotary lime kilns and hydrators, and (4) meetings with the National Air Pollution Control Techniques Advisory Committee (NAPCTAC).

The selection of the best system of emission reduction, considering costs, is based on an evaluation of the incremental impacts, as compared to a typical state standard, on air emissions, ambient concentrations, air pollution control costs, energy requirements, water pollution problems, and solid waste problems. The first step is to select the most effective emission reduction methods for each affected facility. The impacts of the individual methods are then compared to determine the best emission reduction method. The best system to control particulate matter from lime plants is a combination of the best emission reduction method or methods for the kiln and the hydrator, since the emissions from each facility at a lime plant are independent of emissions from other facilities.

8.3.1 Lime Kilns

The rotary lime kiln is the principal source of the emissions of particulate matter at a lime plant. Three emission reduction methods were considered during the development of the proposed standards. These three are fabric filters (baghouses), electrostatic precipitators (ESP), and venturi scrubbers. EPA performed source tests on rotary kilns controlled by each one of the three control devices which show that all are capable of meeting the particulate emission level of 0.15 kilogram per megagram (0.3 pound of limestone feed using system A-1 or B-1, which were previously discussed in Chapter 6.

The results of source tests on the scrubber-controlled rotary kiln show that the system did not meet the level of the proposed particulate standard. The system, however, was operating at a relatively low pressure drop. In EPA's judgment, an increase in the pressure drop through the scrubber would increase the collection efficiency of the device sufficiently to meet an emission rate of 0.15 kg/Mg.

The tests that were performed on the ESP-controlled kilns are not indicative of normal operation since the current trend in the lime manufacturing industry is toward the use of coal as fuel and the kilns that were tested were fired by oil and natural gas. It is expected that this use of coal would produce a more difficult control problem. However, with proper design of the ESP, it is EPA's judgment that the system could easily meet the level of the proposed standard.

Another current trend in the industry is toward the use of dry control systems rather than scrubbers. EPA has published effluent guidelines for the lime manufacturing industry that require that no discharge of water be made from the operation. Fabric filters and ESP's have additional advantages over scrubbers; scrubbers require about six times more energy to operate and produce a sludge rather than the dry solid collected by fabric filters and ESP's. This sludge is more difficult to handle and properly dispose.

Additionally, the temperature of the gases emitted from the scrubber is lower than that from either of the dry systems, and the dispersion of emissions is not as efficient. EPA estimates that approximately 80 percent of the new and modified facilities subject to the proposed standards would use a baghouse to control particulate emissions, with the remaining 20 percent employing an ESP. Since no scrubbers are projected to be used in the future by the lime manufacturing industry, the proposed standard is not based on the use of scrubbers.

The control costs associated with the use of a baghouse, an ESP, and a 22-inch venturi scrubber are presented in chapter 7. EPA has determined that these costs are affordable by the industry. However, the control costs incurred with the use of a 22-inch venturi scrubber are higher than the costs associated with the use of either a baghouse or an ESP.

8.3.2 Hydrators

Hydrators are another significant source of particulate emissions at a lime manufacturing plant. Approximately 10 percent of the lime produced in the U.S. is further treated by hydration. The particulate emissions from this operation consist of particles of hydrated lime in a very moist gas stream. In the domestic industry, scrubbers are generally used to collect the emissions. The captured particulate can be returned to the hydrator along with the scrubbing water and successfully reused. The most common type of scrubber used is a wet fan scrubber with centrifugal separation, although venturi scrubbers could also be used. These scrubbers are not used, however, because of the additional energy requirements and operational costs. Baghouses have been used at a few plants with varying degrees of success. To allow the use of a baghouse, the exhaust gas must be superheated in order to avoid condensation of the near saturated gas stream. This has been shown to be very energy intensive and costly. EPA feels that all hydrators that will be affected by the proposed standards would be likely to use a wet fan scrubber to control particulate emissions.

The control costs associated with the use of scrubbers are presented in Chapter 7, and are found to be very small. The annualized control costs amount to 4 cents per ton of hydrated lime, and are considered to be negligible.

Because of the significant reduction in particulate emissions and the relatively minor associated environmental and economic impacts, EPA concludes that the best system of emission reduction, considering costs, for control of particulate emissions from hydrator units at lime manufacturing plants is a low pressure wet fan scrubber with centrifugal separation.

8.4 SELECTION OF THE FORMAT OF THE PROPOSED STANDARDS

8.4.1 Rotary Lime Kilns

The two options available for use as the format of the proposed particulate standard are a concentration standard or a mass-per-unit-of-feed standard. The format most widely used in the domestic lime manufacturing industry and by State and local control agencies is the mass-per-unit-of-feed standard. A concentration standard would penalize the more energy efficient kiln operations. Since reduced fuel consumption results in smaller exhaust gas volumes, a concentration standard would require the most efficient kiln operators to achieve a higher degree of control. Normally concentration standards are easier to enforce than mass standards. The feed rate of the limestone into the kiln, however, is routinely measured, allowing the emission rate in kilograms of particulate per megagram of limestone feed (kg/Mg) to be calculated directly. EPA has determined, therefore, that since the mass-per-unit-of-limestone feed format is more equitable for the lime producers, this format will be used for the proposed standard.

8.4.2 Hydrators

The options for the format of the proposed standard for the lime hydrator are also a concentration standard or mass per-unit-of-feed standard. A concentration format would not be accurate for this facility, since the gas volume from the hydrator scrubber is not proportional to the production rate and it is not possible to prevent dilution by correcting to any specified percent oxygen and water. The format chosen, therefore, is the mass-per-unit-of-feed format, expressed in the units of kilograms of particulate per megagram of lime feed (kg/Mg).

8.5 SELECTION OF EMISSION LIMITS

The emission limits for control of particulate matter from lime kilns and hydrators at lime manufacturing plants are based on the emission levels attainable by application of the best system of emission reduction, considering costs. The rationale for the selection of the emission limits of the proposed standards is presented in this section.

8.5.1 Rotary Lime Kilns

Lime kilns were tested for particulate emissions at six lime manufacturing plants. Three of the facilities were controlled by baghouses, two by electrostatic precipitators, and one by a venturi scrubber.

Kiln A, controlled by a baghouse, was source tested by EPA. Each of the six stacks that follow the baghouse was tested once over a three-day period. The sum of the particulate catch totalled about 0.23 kg/Mg (0.47 lb/T) at an average concentration of 0.034 g/std m^3-dry basis (0.015 gr/dscf). The average oxygen concentration measured during the tests was 17.5 percent.

Kiln B, controlled by a baghouse, was tested three times. The average particulate concentration measured was 0.08 g/std m^3-dry basis (0.033 gr/dscf) at 7.7 percent O_2. The corresponding emission rate averaged 0.13 kilogram per megagram (0.26 pound per ton).

Kiln C, controlled by an electrostatic precipitator, was tested by EPA three times. The precipitator has two stacks and the data are presented as the average of the two. The average particulate concentration measured was 0.02 g/std m^3-dry basis (0.0068 gr/dscf) at 10.8 percent O_2, which is equivalent to a mass rate of 0.068 kg/Mg (0.135 lb/ton).

Kiln D, which also uses an electrostatic precipitator for control, was tested by EPA on two separate occasions. The first test had only two successful runs. The average concentration of the particulate emissions was 0.08 g/std m^3-dry basis (0.036 gr/dscf) at 10.0 percent O_2. This is equivalent to a mass rate of 0.133 kg/Mg (0.266 lb/ton). Three test runs were performed during the second test. The average particulate concentration was 0.07 g/std m^3-dry basis (0.0303 gr/dscf) at 7.3 percent O_2 which is equivalent to a mass rate of 0.141 kg/Mg (0.282 lb/ton).

Kiln E, which employs a baghouse for particulate control, has three stacks each of which was tested twice. The average particulate concentration recorded for all three stacks was 0.014 g/std m^3-dry basis (0.006 gr/dscf) at 13.5 percent O_2. The equivalent mass rate is 0.041 kg/Mg (0.081 lb/ton).

Kiln F, which is controlled by a venturi scrubber with a pressure drop of 3.7 kilopascals (15 inch water gauge), was also tested three times. The average particulate concentration during the three runs was 0.06 g/std m^3-dry basis (0.027 gr/dscf) at 11.6 percent O_2. The corresponding mass emission rate averaged 0.216 kg/Mg (0.431 lb/ton).

Kilns A, B, and E, which were controlled by baghouses, are considered to be the most representative of the facilities that were tested because they were burning coal as fuel. The dust generation rates measured for these three facilities (pounds of dust collected per pound of lime produced) ranged from 22 to 25 percent. These are higher than the industry reported average of about 17 percent, and therefore represent difficult control situations.

Plant A had the highest emission rate of the six that were tested. The measured oxygen concentration was also highest for this plant. For the kilns tested that were controlled with baghouses, plant A had an average mass emission rate of 0.23 kg/Mg while plant B and plant E had average mass emission rates of 0.13 kg/Mg and 0.041 kg/Mg, respectively. EPA believes that plant A does not represent best technology (considering costs) since the three plants were tested under similar conditions and two plants had much lower emissions than plant A. The data from the source test on plant A, therefore, are not used in the selection of the proposed particulate standard, which is based on the best system of emission reduction.

The scrubber used on Kiln F is also not considered by EPA to represent best technology. The low pressure drop (15 inches water gauge) of this device reduces the collection efficiency, and the data do not support a low particulate standard.indicative of the best system of emission reduction.

Considering, therefore, the test data from the two baghouses and two ESP's that represent best control technology for particulate emissions from rotary lime kilns, the average emissions ranged from 0.041 to 0.141 kg/Mg (0.08 to 0.28 lb/T). It is EPA's judgment that the best control technology is capable of achieving an emission level of 0.15 kilograms per megagram of limestone feed, and the particulate standard is proposed at this level.

8.5.2 Hydrators

Two hydrator units were tested for particulate emissions by EPA. Both units were controlled with wet fan scrubbers of the type discussed in Chapter 4 (Emission Control Technology). Scrubbers were identified as the best system of emission reduction, considering costs, in section 8.3.

Emissions from unit H-A ranged from 0.033 to 0.053 kg/Mg (0.065 to 0.107 lb/ton) and averaged 0.043 kg/Mg (0.084 lb/ton). Emissions from unit H-B ranged from 0.033 to 0.087 kg/Mg (0.066 to 0.173 lb/ton) and averaged 0.058 kg/Mg (0.117 lb/ton).

Based on these data, EPA's judgment is that a well designed and operated scrubber would be able to meet a particulate emission rate of 0.075 kg per megagram (0.15 lb/ton). This standard is supported by five of the six test runs performed on the two hydrator units. The one test run that exceeds this level, when averaged with any two of the remaining five runs, would not cause an average that exceeds 0.075 kg/Mg.

8.6 VISIBLE EMISSION STANDARDS

The opacity level of visible emissions is an indication of the mass concentration of a particular pollutant. Various studies have shown that opacity varies directly with mass concentrations of particulate matter. The applicability and enforcement of opacity standards related to particulate matter have been established in several court cases for facilities subject to new source performance standards (NSPS) under section 111 of the Clean Air Act.

Opacity standards help to assure that emission control systems are properly maintained and operated so as to comply with mass emission standards on a continuous basis. Opacity test methods are quicker, easier to apply, and less costly than concentration/mass tests for particulate matter. Since EPA considers opacity standards to be a necessary supplement to particulate mass emission standards, opacity levels are established as independent enforceable standards.

Where both opacity and concentration/mass standards are applicable to a given source, EPA establishes opacity standards for new source performance standards that are not more restrictive than the corresponding concentration/mass standard. The opacity standard is generally achievable if the source is in compliance with the concentration standard. In specific cases where it can be demonstrated that the opacity standard is being violated while the particulate standard is being met, provisions for individual review are included in Method 9 (39 FR 39872).

Visible emission data were obtained during the development of the proposed standards at seven lime kilns, and at two hydrator units during the time that particulate mass/concentration tests were being performed.

8.6.1 Lime Kilns

Visible emissions data were obtained during particulate tests on lime kilns at five plants. Two of the plants used baghouses for control, two used electrostatic precipitators, and one used a scrubber. All of the 1056 six-minute averages were obtained as specified in EPA Reference Method 9. The diameters of the stacks that were observed and tested varied from 1.3 to 2.7 meters and the recorded data were normalized to a 3.0 meter stack diameter to take this variation into account. The averages range from a low of zero percent opacity at a mass concentration of 0.011 g/std. m^3-dry basis (0.005 gr/dscf), corrected to zero percent oxygen concentration, to a high of 10.6 percent opacity at a mass concentration of 0.24 g/std. m^3-dry basis (0.105 gr/dscf) (zero percent O_2). A summary of the distribution of the normalized visible emissions data is presented in Table 8-1. Over 67 percent of the six-minute averages were equal to zero and over 82 percent of the averages were less than or equal to five percent opacity. Only 0.4 percent of the normalized averages exceeded 10 percent opacity. The highest single average read was 10.6 percent opacity. EPA therefore believes that the best system of emission reduction that is achieving a particulate level of 0.15 kg/Mg would easily meet a visible emissions level of 10 percent opacity.

The purpose of proposing an opacity standard is to ensure continuous compliance with the particulate standard. The level should therefore be selected to reflect the use of the best control technology. The best control system was identified in section 8.3 to be a baghouse or an electrostatic precipitator. The use of one of these control devices would limit particulate emissions to below 0.15 kg/Mg (0.3 lb/ton). At an average volumetric flow rate and zero percent oxygen concentration, this emission level would produce a concentration of about 0.14 g/std. m^3-dry basis (0.06 gr/dscf) and result in consistently low opacity levels.

Table 8-1. SUMMARY OF VISIBLE EMISSIONS DATA

(All opacity averages are normalized to a 3.0 meter stack diameter.)

Kiln	Number of Six-Minute Averages	Distribution of the Six-Minute Averages (% Opacity)			
		=0	0<X≤5	5<X≤10	>10
B	60	58	2	0	0
C	342	239	5	98	0
D1	237	138	60	37	2
D2	193	63	85	43	2
E	204	194	9	1	0
F	20	18	2	0	0
TOTAL	1056	710	163	179	4
% of Total	100%	67.2%	15.4%	17.0%	0.4%

The proposed visible emissions standard of 10 percent opacity takes into account the range of the data base and would require that the best control devices be properly installed, maintained, and operated on a continuous basis. Although EPA projects that baghouses and ESP's will probably be used, a scrubber with a sufficiently high pressure drop could also be used to meet the level of the proposed particulate standard. When a scrubber is used, however, the opacity of the emissions from the stack must be observed at a portion of the plume where condensed water vapor is not present. EPA believes that due to enforcement difficulties an opacity standard would not be effective in this case, and therefore is excluding rotary lime kilns controlled with scrubbers from the proposed opacity standard.

8.6.2 Hydrators

Observation of visible emissions were attempted during particulate testing on two hydrators. Due to the presence of large steam plumes from the scrubber stacks, only one hour of readings could be taken from one unit and no readings were taken on the second. The readings that were observed are not considered to be accurate enough upon which to base an opacity standard for this facility because of the dispersion due to the trailing steam plume. EPA believes that a standard would be ineffective due to enforcement difficulties, and is therefore not at this time proposing an opacity standard for hydrators.

8.7 MODIFICATION AND RECONSTRUCTION CONSIDERATIONS

The proposed standards apply to all rotary lime kilns and hydrators at lime plants which are constructed or modified on or after the date of proposal. Provisions for modification and reconstruction are discussed in Chapter 5 along with the various physical and operational changes that are expected to occur at lime plants.

Four cases were considered for possible modifidation and reconstruction of lime kilns. These are:

(1) Conversion from natural gas or fuel oil to coal firing;

(2) Addition of a stone preheater to an existing kiln;

(3) Addition of internal bottles to an existing kiln to improve fuel efficiency;

and (4) Expanding the capacity of the production limiting component of the facility (debottlenecking).

There appears to be no technical basis for excluding any of the above cases from the modification and reconstruction provisions of the regulations. In all cases, the costs and economic impacts associated with the control of the increased emissions have been judged to be affordable. The basis for judging the affordability of each case is presented in detail in chapter 7, Economic Impact. No special allowances or exemptions are proposed for the cases considered.

No cases of modification of hydrators have been considered since it is assumed that the units would either be reconstructed or replaced entirely at the end of the service life. Should the addition of replacement parts which cost more than 50 percent of the cost of a new unit be made, then the reconstruction provisions would apply, and the proposed standard of 0.075 kg/Mg (0.15 lb/ton) would be applicable.

8.8 SELECTION OF MONITORING REQUIREMENTS

Under section 114(a) of the Clean Air Act, the Administrator may require the owner or operator of any stationary emission source to install, use, and maintain monitoring equipment or methods. EPA has exercised this authority in the standards of performance for several source categories by requiring the monitoring of pollutant emissions or parameters that are indicators of pollutant emissions. The requirements for continuous monitoring are necessary to determine if a control device is being properly operated and maintained. It also aids in determining when and if a performance test should be required. The costs of purchasing, installing, and operating the monitoring devices must be considered reasonable and affordable.

8.8.1 Lime Kilns

Particulate emissions from rotary lime kilns at lime plants are controlled with baghouses, electrostatic precipitators, or scrubbers. All three devices have been identified as representing the best control technology, considering costs, and capable of meeting the proposed standard of 0.15 kg/Mg (0.3 lb/ton). Opacity monitoring systems are well demonstrated on sources using these types of control systems as being effective for insuring proper operation and maintenance and the costs are considered reasonable for lime plants; therefore, the use of a continuous opacity monitor is required for lime kilns.

Visible emissions are more difficult to record on facilities using scrubbers for control due to the presence of entrained water droplets in the stack and the corresponding steam plume. This causes an error in measurement which cannot be quantified and which would make the recorded data questionable. Therefore, continuous monitoring of plume opacity from the lime kiln will not be required when a scrubber is used as the control device. There are, however, other methods of monitoring the proper operation and maintenance of the scrubber. The pressure drop across the scrubber and the liquid flow rate are indicators of the scrubber performance. The proposed regulations, therefore, require the use of monitoring devices to continuously record the pressure drop and the scrubbing liquid supply pressure to the control device. The performance of the scrubber could then be judged at any time by comparing the values of the pressure parameters with the values at the time the performance test was performed.

8.8.2 Hydrators

Particulate emissions from hydrators will be controlled with a scrubber to meet the proposed standard of 0.075 kg/Mg (0.15 lb/ton). Due to the large attached steam plume from the scrubber stack, visible emissions readings could not be accurately recorded during the source tests. Therefore, no opacity standard is proposed for hydrators. Monitoring of the operating parameters of the scrubber, however, presents a good indication of scrubber performance. The proposed regulations therefore require the monitoring of the water flow rate to the scrubber and of the electric current in amperes used by the scrubber. The operation of the scrubber may then at any time be compared to the operation during the original performance test.

8.8.3 Excess Emissions

As specified in sections 60.7(b) and (c) of the regulations (Notification and Recordkeeping), the operator of any source subject to the proposed standards would be required to maintain records of the occurrence and duration of any periods of start-up, shutdown, or malfunction in the operation of an affected facility, any malfunction of the air pollution control equipment, or any periods during which a continuous monitoring system or monitoring device is not operating. All excess emissions as defined in the applicable subpart must be reported to EPA for each calendar quarter. Generally, excess emissions are defined in terms of the applicable standards as discussed below.

Lime Kilns

Excess emissions of opacity from a lime kiln are defined as all six-minute average opacity values that exceed the proposed standard of 10 percent opacity, except those occurring during start-up, shutdown, or malfunction of the facility or control device. The analysis of the opacity data recorded by EPA indicates that less than 0.5 percent of all six-minute average opacities will exceed 10 percent when the particulate standard is being met. Where scrubbers are used, owners or operators are required to maintain records of the pressure drop in the gas stream and water supply pressure to the scrubber for a period of two years; however, excess emission reports are not required.

Hydrators

No definition of excess emissions from hydrators is included in the proposed regulations since no opacity standard has been developed.

8.9 SELECTION OF PERFORMANCE TEST METHODS

The test methods for the measurement of particulate matter from lime kilns and hydrators at lime manufacturing plants are specified for determining compliance with the proposed standards. EPA Reference Method 5 was used to gather the particulate emissions data from the six kilns and the two hydrators that were tested. EPA Reference Method 9 was used to gather the 1056 six-minute average opacity values that were used to support the proposed visible emission standard for rotary lime kilns. In addition, EPA Reference Method 2 for velocity and volumetric flow rate, Reference Method 3 for gas analysis, Reference Method 4 for the determination of stack gas moisture, Reference Method 6 for SO_2, Reference Method 7 for NO_x, and Reference Method 10 for CO were used to develop the data base. All of these standard Reference Methods have been applied to other stationary source categories for which standards of performance have been promulgated, and have been published in Appendix A to Part 60 of the Federal Code.

Method 5 and Method 9 are sufficient to determine compliance with the proposed particulate and opacity standards. Therefore, they are specified in the regulations as the required performance test methods. Method 1, Method 2, Method 3, and Method 4 are also required to supply the additional data necessary to determine compliance with the proposed standards.

REFERENCES FOR CHAPTER 8

1. "Impact of New Source Performance Standards on 1985 National Emissions from Stationary Sources," prepared for the U. S. Environmental Protection Agency by The Research Corporation of New England, Contract 68-02-1382, Task No. 3, October 24, 1975.
2. "Priorities and Procedures for the Development of Standards of Performance for New Stationary Sources of Atmospheric Emissions," prepared for the U. S. Environmental Protection Agency by Argonne National Laboratory, Contract No. IAG-04-0463, Project No. 2, 1974.
3. "Prevention of Significant Air Quality Deterioration," Federal Register 39 FR 42510 (December 5, 1974).
4. Bunyard, F. L., EPA Trip Report of visit with F. Schwarzkoph of Kennedy Van Saun (September 29, 1975).

APPENDIX A. EVOLUTION OF THE PROPOSED STANDARDS

A.1 LITERATURE REVIEW

Available literature was reviewed to gather background information on the industry and its progress in control of its air pollution emissions. A prime literature source was the Air Pollution Technical Information Center, EPA, which routinely abstracts and catalogues literature related to air pollution. Other sources were periodicals on air pollution and the industry, meetings of technical societies and pertinent textbooks.

A.2 SELECTION OF PLANTS FOR SOURCE SAMPLING

As a consequence of reviewing the literature and contacting several representatives of the lime industry several plants were identified which were reported to effectively control emissions from rotary lime kilns and lime hydrators. Thirty nine plants were subsequently visited by the EPA and its contractors. During the visits, the visibility of emissions was evaluated and information was obtained on the process and the equipment used to control emissions. Six of these plants were deemed to employ best systems of emission reduction for rotary lime kilns and two plants had lime hydrators with similar well-controlled emissions. All of these plants were source tested and the results of these tests are found in Appendix C. Two additional plants burning high sulfur coal in five rotary kilns were located and source tested for SO_2 emissions. The results of these tests can also be found in Appendix C.

The capacities of the rotary lime kilns tested ranged from 240 to 720 tons of product per day. This size range is typical for the lime industry. The hydrators that were tested were also typical of the industry, ranging from 17 to 22 tons per hour of product. Although many of the facilities were rather old, the long rotary kilns and hydrators tested are the same as ones that would be built today.

In addition to the information provided by the EPA source tests, this report also includes emission data from other tests. These plants were sampled in accordance with EPA techniques. This data is included to further prove the effectiveness of the control techniques.

A.3 CHRONOLOG

Date	Activity
October 31, 1973	Visit to Bethlehem Mines lime plant in Annville, Pennsylvania.
November 8, 1973	Visit to Pfizer lime plant in Gibsonburg, Ohio.
January 22-24, 1974	Emission testing at Bethlehem Mines Corporation, Annville, Pennsylvania, lime plant.
January 31, 1974	Visit to Basic lime plant in Port St. Joe, Florida.
February 8, 1974	Visit to Woodville Lime and Chemical Company plant in Woodville, Ohio.
February 12, 1974	Visit to the Flintkote Company lime plant in Industry, California.
February 13, 1974	Visit to the Flintkote Company lime plant in Henderson, Nevada.

February 20, 1974	Visit to Dow Chemical Company lime plant in Freeport, Texas.
February 21, 1974	Visit to Alcoa lime plant in Port Comfort, Texas.
March 18, 1974	Section 114 letter sent to Mr. Leedecker of Bethlehem Mines Corporation.
April 9, 1974	Visit to Marblehead Lime Company plant in Gary, Indiana.
April 15-18, 1974	Emission test at The Flintkote Company lime plant in Industry, California.
April 22-25, 1974	Emission test at The Flintkote Company lime plant in Henderson, Nevada.
April 30-May 3, 1974	Emission test at Dow Chemical lime plant in Freeport, Texas.
May 14, 1974	Section 114 response received from Mr. Leedecker of Bethlehem Mines Corporation.
May 20-21, 1974	Emission test at Woodville Lime and Chemical Company plant in Woodville, Ohio.
June 10-13, 1974	Emission test at Marblehead Lime Company plant in Gary, Indiana.
July 2, 1974	Section 114 letter sent to Mr. Mathew of The Flintkote Company.
July 8-10, 1974	Emission test at Woodville Lime and Chemical Company plant in Woodville, Ohio.
August 6-8, 1974	Emission test at Woodville Lime and Chemical Company plant in Woodville, Ohio.

September 4, 1974	Section 114 letter sent to Mr. Jorgensen of Marblehead Lime Company.
September 4, 1974	Section 114 letter sent to Mr. Laman of Dow Chemical Company.
October 8, 1974	Section 114 response received from Mr. Laman of Dow Chemical Company.
October 14, 1974	Section 114 response received from Mr. Mathew of The Flintkote Company.
October 23, 1974	Section 114 response received from Mr. Jorgensen of Marblehead Lime Company.
February 28, 1975	Section 114 letter sent to Mr. Campbell of Bethlehem Mine Corporation.
March 12, 1975	Visit to Allied Products Company lime plant in Montevallo, Alabama.
March 13, 1975	Visit to Austin White Company lime plant in McNeil, Texas.
March 14, 1975	Visit to Texas Lime plant in Cleburne, Texas.
March 17, 1975	Visit to The Flintkote Company lime plant in Nelson, Arizona.
March 27, 1975	Section 114 response received from Mr. Campbell of Bethlehem Mines Corporation.
April 4, 1975	Section 114 letter sent to Mr. Jorgensen of Marblehead Lime Company.
April 11, 1975	Meeting with Woodville Lime and Chemical Company to discuss results of emission testing.

May 12, 1975	Section 114 letter response received from Mr. Jorgensen of Marblehead Lime Company.
May 27, 1975	Section 114 letter sent to Mr. Tadsen of Woodville Lime and Chemical Company.
June 19, 1975	Section 114 letter sent to Mr. Wilson of Allied Products Company.
June 23, 1975	Section 114 letter sent to Mr. McCandlish of The Flintkote Company.
June 26, 1975	Visit to Allied Products Company lime plant in Montevallo, Alabama.
June 25, 1975	Visit to Martin Marietta Chemicals Calera, Alabama lime plant.
July 21, 1975	Section 114 response received from Mr. McCandlish of The Flintkote Company.
August 6, 1975	Visit to Huron Lime Company lime plant in Huron, Ohio.
September 8-14,17, 1975	Emission testing at Martin Marietta Chemicals Calera, Alabama, lime plant.
September 15-17, 1975	Emission testing at Allied Products Company Montevallo, Alabama lime plant.
September 23, 1975	Meeting with Florian Schwartzkoph of Kennedy Van Saun.
November 4, 1975	Visit to Bethlehem Mines Corporation lime plant in Hanover, Pa.
November 5, 1975	Visit to Warner Company lime plant in Bellefonte, Pa.

November 11, 1975	Visit to J. E. Baker Company lime plant in Millersville, Ohio.
November 12, 1975	Visit to Martin Marietta Chemicals Woodville, Ohio lime plant.
December 2-9, 1975	Emission test at J. E. Baker Company Millersville, Ohio lime plant.
January 27, 1976	Section 114 response received from Mr. Wilson of Allied Products Company.
January 27-31, 1976	Emission test at Martin Marietta Chemicals Woodville, Ohio lime plant.
February 4, 1976	Section 114 response received from Mr. Tadsen of Woodville Lime and Chemical Company.
February 11, 1976	Meeting with the National Lime Association in Durham, North Carolina.
March 9, 1976	Working Group Meeting held in Durham, N.C.
March 18, 1976	National Air Pollution Control Techniques Advisory Committee Meeting.
April 30, 1976	Meeting held with National Lime Association.
May 19, 1976	Meeting held with the National Lime Association in Washington, D.C.
June 30, 1976	Meeting held with the National Lime Association, Marblehead Lime Company, and Pfizer Lime Company in Durham, N.C.
December 21, 1976	EPA Working Group reviewed the proposal package in Durham, N.C.
February 11-18, 1977	Review of the standards package by the EPA Steering Committee in Washington, D.C.

APPENDIX B

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

This appendix consists of a reference system, cross-indexed with the October 21, 1974, Federal Register (39 FR 37419) containing the Agency guidelines concerning the preparation of Environmental Impact Statements. This index can be used to identify sections of the document which contain data and information germane to any portion of the Federal Register guidelines.

CROSS INDEXED REFERENCE SYSTEM TO HIGHLIGHT ENVIRONMENTAL IMPACT PORTIONS OF THE DOCUMENT

Agency Guideline for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Standards Support and Environmental Impact Statement
1. Background and description of the proposed action.	
-Describe the recommended or proposed action and its purpose.	The proposed standards are summarized in chapter 1, section 1.1. The statutory basis for the proposed standards (section 111 of the Clean Air Act, as amended) is discussed in chapter 2, Introduction. The purpose of the proposed standards is discussed in chapter 8, sections 8.1 and 8.2.
-The relationship to other actions and proposals significantly affected by the proposed action shall be discussed, including not only other Agency activities but also those of other governmental and private organizations.	Water effluent limitations for point sources in the lime manufacturing industry are discussed in chapter 6, Environmental Impact.
2. Alternatives to the proposed action.	
-Describe and objectively weigh reasonable alternatives to the proposed action, to the extent such alternatives are permitted by the law. . . For use as a reference point to which other actions can be compared, the analysis of alternatives should include the alternative of taking no action, or of postponing action. In addition, the analysis should include alternatives having different environmental impacts, including proposing standards, criteria, procedures, or actions of varying degrees of stringency. When appropriate, actions with similar environmental impacts but based on different technical approaches should be discussed. This analysis shall evaluate alternatives in such a manner that reviewers can judge their relative desirability.	The alternative control systems used in the development of the proposed standards are presented in chapter 6, section 6.1.1. A discussion of the alternative of taking no action and that of delaying the proposed action is also presented in chapter 6. The selection of the best system for emission reduction, considering costs, is presented in chapter 8, section 8.3. The alternative formats for the proposed standards are discussed and the rationale for the selection of the proposed formats are discussed in chapter 8, section 8.4. The rationale for the selection of the particulate emission limits for the affected facilities is discussed in chapter 8, section 8.5.

CROSS INDEXED REFERENCE SYSTEM TO HIGHLIGHT ENVIRONMENTAL IMPACT PORTIONS OF THE DOCUMENT (continued)

Agency Guideline for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Standards Support and Environmental Impact Statement
	The rationale for the selection of the visible emissions standard for the lime kiln is presented in chapter 8, section 8.6
-The analysis should be sufficiently detailed to reveal the Agency's comparative evaluation of the beneficial and adverse environmental, health, social, and economic effects of the proposed action and each reasonable alternative.	A summary of the environmental and economic impacts associated with the proposed standards are presented in chapter 1, section 1.2.
	A detailed discussion of the environmental effects of each of the alternative control systems can be found in chapter 6. This chapter includes a discussion of the beneficial and adverse impacts on air, water, solid waste, energy, noise, radiation, and other environmental considerations.
	A detailed analysis of the costs and economic impacts associated with the proposed standards can be found in chapter 7.
-Where the authorizing legislation limits the Agency from taking certain factors into account in its decision making, the comparative evaluation should discuss all relevant factors, but clearly identify those factors which the authorizing legislation requires to be the basis of the decision making.	The factors which the authorizing legislation requires to be the basis of the decision making are discussed in chapter 2.
-In addition, the reasons why the proposed action is believed by the Agency to be the best course of action shall be explained.	The rationale for controlling particulate matter from lime plants through standards of performance is discussed in chapter 8, sections 8.1 and 8.2.

CROSS INDEXED REFERENCE SYSTEM TO HIGHLIGHT ENVIRONMENTAL IMPACT PORTIONS OF THE DOCUMENT (continued)

Agency Guideline for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Standards Support and Environmental Impact Statement
3. Environmental impact of the proposed action.	
A. Primary impact Primary impacts are those that can be attributed directly to the action, such as reduced levels of specific pollutants brought about by a new standard and the physical changes that occur in the various media with this reduction.	The primary impacts on mass emissions and ambient air quality due to the alternative control systems are discussed in chapter 6. These impacts are also summarized in Table 1-2, Matrix of Environmental and Economic Impacts of the Alternative Standards presented in chapter 1.
B. Secondary impact Secondary impacts are indirect or induced impacts. For example, mandatory reduction of specific pollutants brought about by a new standard could result in the adoption of control technology that exacerbates another pollution problem and would be a secondary impact.	The secondary environmental impacts attributable to the alternative control systems are discussed in chapter 6. Secondary impacts on air quality are discussed in chapter 6, section 6.1.2. Secondary impacts on solid waste are discussed in chapter 6, section 6.1.4. The anticipated control system is discussed in chapter 6, section 6.1.5.
4. Other considerations.	
A. Adverse impacts which cannot be avoided should the proposal be implemented. Describe the kinds and magnitudes of adverse impacts which cannot be reduced in severity to an	A summary of the potential adverse environmental and economic impacts associated with the proposed standards and the alternatives that were considered is discussed in chapter 1, section 1.2, and in chapter 6.

CROSS INDEXED REFERENCE SYSTEM TO HIGHLIGHT ENVIRONMENTAL IMPACT PORTIONS OF THE DOCUMENT (continued)

Agency Guideline for Preparing Regulatory Action Environmental Impact Statements (39 FR 34719)	Location Within the Standards Support and Environmental Impact Statement
acceptable level or which can be reduced to an acceptable level but not eliminated. These may include air or water pollution, damage to ecological systems, reduction in economic activities, threats to health, or undesirable land use patterns. Remedial, protective, and mitigative measures which will be taken as part of the proposed action shall be identified.	
B. Relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity. Describe the extent to which the proposed action involves trade-offs between short-term environmental gains at the expense of long-term losses or vice versa and the extent to which the proposed action forecloses future options. Special attention shall be given to effects which pose long-term risks to health or safety. In addition, the timing of the proposed action shall be explained and justified.	The discussion of the use of man's environment is included in chapter 6. A discussion of the effects of emissions from lime plants is included in chapter 8, section 8.1 and section 8.2.
C. Irreversible and irretrievalbe commitments of resources which would be involved in the proposed action should it be implemented. Describe the extent to which the proposed action curtails the diversity and range of beneficial uses of the environment. For example, irreversible damage can result if a standard is not sufficiently stringent.	Irreversible and irretirevable commitments of resources are discussed in chapter 6, section 6.1.6.1.

APPENDIX C. SUMMARY OF PARTICULATE AND GASEOUS EMISSION TEST RESULTS

A program was undertaken by EPA to evaluate the particulate control techniques available for installation on new or substantially modified rotary lime kilns and lime hydrators. Information was obtained from the literature, contacts with companies which manufacture lime, and control agencies. The results of particulate and gaseous emission tests at five plants which produce lime in rotary kilns are included in this section. An additional two plants burning high sulfur coal were tested for SO_2 emissions only. The results of particulate emission tests on two lime hydrators tested by EPA and one tested by plant personnel are also included. All of these plants were typical of modern installations and used best technology for control of particulate emissions. The rotary lime kiln control devices sampled for particulates were also tested for carbon monoxide, nitrogen dioxide, sulfur dioxide, and visible emissions. The rotary kiln test results are summarized in Table C-1 through C-3 and the complete results are in Tables C-4 through C-51. The hydrator emission tests are summarized in Table C-52 and the complete results are in Tables C-53 through C-55. Emission tests performed on the Plant A baghouse are included at the end of Appendix C because the test results (Table C-56) seem questionable. Visible emission results are in Table C-57 to C-63.

Plant B

The exhaust gases from the rotary kiln are cooled by water sprays prior to entering an American Air Filter Co. baghouse. The kiln is coal fired and has a rated lime production of 650 TPD. Two of four baghouse stacks were tested three times on consecutive days by the EPA contractor. Plant personnel tested the other two stacks during the same time periods. EPA Method 5 was used during testing. Results of the plant personnel tests were contained in a 114 letter response. The complete results of the EPA testing are shown in Table C-4 and these results are averaged with the plant personnel results to arrive at the total emissions (Table C-5). Kiln production remained steady at 720 tons/day during the sampling period and the baghouse pressure drop was from 4.1 to 4.4 IWC. This production rate is 111 percent of the rated capacity for the kiln. Results of the tests showed that the baghouse is an effective control device even when a plant is operated over rated capacity. Visible emissions averaged zero throughout each test with only a few opacity readings of 5. The complete visible emissions results are shown in Tables C-6 through C-11.

Plant B Baghouse -

Type - Pressure Baghouse
Manufacturer - American Air Filter
Bag Material - Silicon & graphite finished fiberglass fabric
No. of Compartments - 14 compartments with 60 bags in each compartment
No. of Stacks - 4
Design Pressure Drop - 8 I.W.C. maximum
Cloth Area - 80,108 ft^2
Bag Cleaning - Reverse air flow (one compartment at a time)
Cloth Area (operating) - 74,386 ft^2
Fan Design - 126,000 ACFM @ 550°F
Design Air to Cloth Ratio - 1.7:1

Plant C

Three rotary kilns process dolomitic limestone into quicklime which is then slaked to the hydrate and used to precipitate magnesium hydroxide from sea water. The ultimate product which is derived after additional processing is magnesium metal. The kilns are fired by natural gas and have a design capacity of 250 tons per day each. During normal operation only two of the kilns are used. Exit gas from the kilns is cooled by water sprays, enters a common plenum, and is then distributed to the two chambers of an electrostatic precipitator.

The two stacks from the ESP were sampled simultaneously. Production from the two kilns controlled by the ESP was steady at about 485 tons/day which is 97 percent of the maximum design production of 500 tons/day. Each of the three tests yielded fairly consistent results which shows that the ESP is achieving excellent particulate emission control. These results are summarized in Table C-12. Visible emissions data obtained throughout the test periods are shown in Tables C-13 through C-24. The opacities were less than 5 percent throughout most of the testing.

Plant C Electrostatic Precipitator -

Type - Positive Pressure

Manufacturer - Western Precipitation Division

Plate Area - 72,576 ft^2 total

No. of Chambers - 2

No. of Fields - 3

Design Residence Time (For 3 kilns) - 7.06 sec.

Pressure Drop - 2 I.W.C. (Maximum including inlet and stack)

Flow Design - 225,000 ACFM @ 500°F with 3 kilns operating

Cleaning - NAVCO pneumatic rappers

Guaranteed Efficiency - 99%

Design Plate Area per 1,000 ACFM - 323 ft^2/1,000 ACFM

Operating Residence Time (For 2 kilns) - 7.59 sec.

Operating Plate Area per 1,000 ACFM - 347 ft^2/1,000 ACFM

Plant D

This facility's rotary lime kiln processes dolomitic stone and operates on a mixture of Number 6 fuel oil and natural gas. A majority of the lime is used in BOF furnaces. The kiln has a design production rate of 350 tons per day. Exit gas is cooled using a combination of water injection and tempering air before entering a Buell electrostatic precipitator.

The first test attempted on this lime kiln ESP occurred on May 20 and 21, 1974. Process operational problems and ESP maintenance difficulties resulted in high emissions and cancellation of the test program. Opacity readings were taken and ranged between 10 and 40 percent. A Lear Siegler in-stack continuous visible emission monitor was used and measured opacities ranging from 10 to 20 percent.

The second group of tests was conducted on July 8, 9, and 10. Testing problems on July 8 made the results of the test highly questionable (a probe glass liner tip was found to be broken which may have resulted in obtaining emission values that were too high). The second and third tests encountered no difficulties and opacity readings normally ranged from 0 to 5 percent. A test data is shown in Table C-25 and the opacity data is shown in Table C-26 through C-31. The plant was operating at 106 percent of capacity during testing. A fourth test, intendhd to replace the questionable values obtained during the first test, was attempted on July 10 and 11. This test was never completed because stack opacities rose to the 15 and 20 percent range. The kiln was shut down and an inspection of the ESP revealed that the charge plates were covered with 1 inch of a substance which was reducing the collection efficiency. Cleaning the plates would require shutdown of the kiln for a week so testing was stopped.

The last test program was performed on August 6, 7, and 8, 1974. Emissions from the first run were greater than the second and third runs. This was attributed to some process adjustments which were made during the first test. These results are summarized in Table C-32. During the first test run most opacity readings were 5 percent with some readings of 10 percent. During the last two tests no problems occurred and the opacity values were 0 to 5 percent. The opacity data are summarized in Table C-3 and all of the opacity data is shown in Tables C-33 through C-38.

Lime production during the three test programs was as follows:

Tests 5/20-21	350 tons/day
Tests 7/8-10	370 tons/day
Tests 8/6-8	300 tons/day

The production drop (to 86 percent of capacity) during the last test was not realized until after testing has been completed. Average emission concentrations from the July and August test programs are about the same.

Plant D Electrostatic Precipitator -

Type - Positive Pressure

Manufacturer - Buell Engineering Company

Plate Area - 28,800 ft^2

No. of Chambers - 1

No. of Fields - 2

Design Residence Time - 10.0 sec.

Pressure Drop - 0.3 I.W.C.

Flow Design - 64,984 ACFM @ 600°F

Cleaning - Buell electromagnetic rappers

Guaranteed Efficiency - 99.7%

Design Plate Area per 1,000 ACFM - 443 ft^2/1,000 ACFM

Operating Residence Time - 9.4 sec.

Operating Plate Area per 1,000 ACFM - 437 ft^2/1,000 ACFM

Plant E

This facility's rotary lime kiln was source tested. The kiln has a nominal design capacity of 264 tons per day of high calcium lime, which is used in the paper and pulp industry. The kiln off-gas is cooled by an atomized water spray and then ducted to the American Air Filter baghouse.

Each of the three baghouse stacks was tested twice. During the testing the kiln production was a steady 240 tons per day, or 91 percent of the rated capacity. Visible emission readings were taken during the testing and they were almost always zero. These results are shown in Tables C-40 through C-47. Simultaneous sulfur dioxide tests were performed with EPA Method 6 at the inlet and outlet to the baghouse in an attempt to determine the effect the baghouse had on SO_2. These tests proved inconclusive since only one outlet test yielded results. Tests performed with Dynascience continuous gas monitor showed an approximately 40 percent reduction in SO_2 across the baghouse. A complete summary of the emission test results is shown in Table C-39.

Plant E Baghouse -

Type - Pressure Baghouse

Manufacturer - American Air Filter Corporation, in operation March 1975

Bag Material - Silicon & graphite finished fiberglass fabric

No. of Compartments - 6 compartments with 72 bags in each compartment

No. of Stacks - 3

Design Pressure Drop - 2.5 I.W.C.

Cloth Area - 41,196 ft^2

Bag Cleaning - Reverse air flow (one compartment at a time)

Cloth Area (operating) - 34,330 ft^2

Fan Design - 65,000 ACFM (250 Hp @ 880 RPM)

Design Air to Cloth Ratio - 1.89:1

Plant F

The rotary lime kiln was source tested. The kiln has a rated production capacity of 650 tons of high calcium lime per day. Emissions are controlled by 12 Buell cyclones and dual ASE, Incorporated venturi water scrubbers. The kiln off-gas is cooled by an atomized water spray. The exhaust from the dual venturi scrubbers is sent to cyclonic separators and is then reunited and vented to the atmosphere through a single stack. This stack was tested three times using EPA Method 5.

The stack was tested over a 3 day period. The kiln production was steady at 620 tons/day which is 95 percent of the maximum design capacity for the kiln. The results of this test show the particulate removal efficiency of a 15 I.W.C. water scrubber. Three simultaneous inlet and outlet SO_2 tests were attempted but problems were encountered in the SO_2 testing and only one of the six tests yielded any results. A summary of the emission tests is shown in Table C-39. Visible emission readings were attempted during the particulate testing but the large steam plume made it impossible to make any meaningful readings. A summary of the opacity readings is shown in Table C-49.

Plant F Venturi Scrubber -

Type - Dual Venturi Water Scrubbers

Manufacturer - ASE, Inc. installed Nov. 1973

Design Pressure Drop - 15 I.W.C.

Design Throat Water Flowrate - 800 gallons per minute per throat

Air Flow Rate - 91,000 ACFM @ 650°F per venturi throat

Type Precleaners - 12 Buell cyclones

Plant G

This facility has 2 rotary lime kilns, one designed to produce 350 tons of lime per day and another designed to produce 280 tons of dead burned dolomite (DBD) per day. The fuel for these kilns is high sulfur (3.53 and 2.96% S) coal. Both kilns are controlled by identical Air Pollution Industries water scrubbers and their products are used in the steel industry. There is no cooling or precleaning of the kiln off-gas before it reaches the scrubbers.

Six EPA Method 6 tests were run at the inlet and outlet of each kiln. The tests on the DBD kiln were run simultaneously. The lime kiln was producing 320 tons of lime per day during the outlet testing and the DBD kiln was producing 280 tons per day during its testing. No visible emission readings were performed during the testing. A complete summary of the SO_2 testing is found in Table C-40.

Plant G Venturi Scrubber -

Type - Venturi Water Scrubber

Manufacturer - Air Pollution Industries, Inc.

Design Pressure Drop - 15 I.W.C.

Design Throat Flow Rate - 2200 gpm

Design Air Flow Rate - 62000 ACFM @ 160°F

Precleaners - None

Guaranteed Efficiency - 0.39 gr/DSCF @ 70°F

Plant H

This facility has three rotary kilns whose off-gas is ducted to one 22 compartment baghouse. Two of the kilns process dolomitic limestone to produce 720 and 960 tons of lime per day, respectively, for use in the steel industry. Each has a Kennedy Van Saun stone preheater and 21 Research Cottrell Multiclones.

The preheater and cyclones cool the off-gas sufficiently for cleaning in the baghouse. The third kiln produces 400 tons per day of DBD. There is no preheater but there are Western Precipitation cyclones and tempering air can be added to the kiln off-gas before it enters the baghouse. All of the kilns are fired by high sulfur (2-3% S) coal.

Inlet SO_2 testing was attempted by both EPA Method 6 and continuous instrumental SO_2 analyzers. Most of the results obtained were questionable due to lime dust interference, but the indication from the tests was that most of the SO_2 was from the Number 6 (DBD) kiln. EPA Method 6 testing on the DBD kiln gave 833, 74 and 78 parts per million (ppm) SO_2, and the continuous monitor gave concentrations ranging from 580 tc 1300 ppm. During the baghouse testing, the concentration at the DBD inlet ranged from 373-416 ppm. The highest recorded SO_2 from either of the lime kilns was 200 ppm, and the concentration averaged around 130 ppm. During the outlet testing, the inlet SO_2 concentrations from the lime kilns was negligable according to the instruments, but this was probably due to lime interference with the instruments. Based on the limited amount of inlet data available, the indication is that over half of the SO_2 in the baghouse came from the DBD kiln and the rest was from the two lime kilns.

Simultaneous EPA Method 6 SO_2 tests were performed on six of the 22 baghouse stacks during each outlet sampling period. Six of these runs were performed over a two day period while the plant was operating normally for a total of 36 SO_2 tests. Sampling difficulties invalidated 2 of the 36 tests. At least one test was performed on each baghouse stack. The results were averaged to arrive at the SO_2 emission rate for the three kiln-baghouse systems. A summary of these tests is shown in Table C-51. The three kilns operated at over 93 percent of capacity during testing. No visible emissions were seen from the baghouse during the entire week of the testing.

Plant H Baghouse -

Type - Pressure Baghouse

Manufacturer - Western Precipitation, in operation June 1975

Bag Material - Graphite, silicon and teflon coated glass

No. of Compartments - 22 compartments with 672 bags in each compartment

No. of Stacks - 22

Design Pressure Drop - 3 I.W.C.

Cloth Area - 214,368 ft^2

Bag Cleaning - Reverse air flow (one compartment at a time)

Cloth Area (operating) - 194,880

Design Air to Cloth Ratio - 2.04:1 cleaning 2.24:1

Fan Design 2 - 115,000 ACFM, 1000 Hp @ 500°F
22 - 19,600 ACFM, 100 Hp @ 550°F

C.2 LIME HYDRATION FACILTIES

Plant H-A

This facility produces calcium hydroxide in a calcitic lime atmospheric hydrator. The plant is designed so that 14 tons per hour of lime is hydrated into 17 to 18 tons of hydrated lime. The entrained particulate is scrubbed out of the gas stream in a Ducon UW-4 Dynamic Water Scrubber. Twenty gallons of water per minute are used to scrub the particulate out of the off-gas stream and are then fed into the pug mill premixer as part of the slaking water. The gases out of the scrubber have 40 percent moisture content.

Three particulate tests were performed at the hydrator stack. Tests 1 and 2 were of four hour duration and test 3 was two hours long. The plant was operating at capacity throughout the testing. Visible emission data were recorded for one hour during the third test but no visible emissions were discernable due to the large steam plume. The emission data is shown in Table C-53 and the opacity data is shown in Table C-54.

Plant H-B

This facility is designed to produce 22 tons per hour of high calcium hydrated lime from 18 tons of lime feed in an atmospheric hydrator. The hydrator off-gas is scrubbed in a Ducon UW-4 Dynamic Water Scrubber. Twenty gallons of water per minute is fed to the scrubber fan to remove the particulate. The off-gas of the scrubber has a 78 percent moisture content.

Three 128 minute EPA Method 5 particulate tests were performed on the hydrator stack. During testing the plant was operating at capacity. The results of the emission testing are shown in Table C-55. The large steam plume and the overcast background during the particulate testing made it very difficult to discern visible emissions. For this reason no visible emission data were recorded.

Table C-1
Rotary Lime Kilns
Summary of Particulate Test Results

Plant	B	C	D(1)	D(2)	E	F
Stone Feed Rate-tons/yr	60	40.4	32.6	26.3	19	51.6
Product TPD	720	485	370	300	226	620
Control Equipment	Baghouse	ESP	ESP		Baghouse	Scrubber
Fuel	Coal	Gas	Oil & Gas		Coal	Coal & Gas
Stack Effluent						
Flow Rate-ACFM	133,700	180,000	68,800	65,900	48,100	137,000
Flow Rate-DSCFM	72,400	92,500	28,000	28,000	30,900	95,100
Temperature-°F	372	394	672	642	270	149
Water Vapor-Vol %	15.3	18.0	11.8	10.5	10.5	19.8
CO_2-Vol % dry	19.3	9.5	20.3	20.7	9.2	12.9
O_2-Vol % dry	8.1	10.8	10.0	7.3	13.5	11.6
CO-Vol % dry	0	0	0	0	0	0
N_2 & other gases Vol % dry	72.6	79.7	69.7	72.0	77.3	75.5
Particulate Emissions						
Probe & Filter Catch						
gr/ACF	0.012	0.0035	0.015	0.0129	0.0038	0.0190
gr/DSCF	0.022	0.0068	0.036	0.0303	0.0059	0.0274
lb/hr	13.3	5.47	8.7	7.42	1.56	22.26
lb/ton of feed	0.222	0.135	0.266	0.282	0.081	0.431
kg/Mg ton of feed	0.111	0.068	0.133	0.141	0.041	0.216

Table C-2. SUMMARY OF SO_2 TEST RESULTS

Plant	Control Device	Limestone Feed Rate (ton/hr)	Fuel % Sulfur Content	Input SO_2 From Fuel (lb/hr)	Inlet to Control Device SO_2			Outlet from Control Device SO_2			% SO_2 Reduction Across Control Device	Total % Removal Efficiency
					ppm	lb/hr	lb/ton	ppm	lb/hr	lb/ton		
B	BH[b]	60	0.6	128	*	*	*	13	9.36	0.15	*	93
C	ESP[c]	20.4	0	0	*	*	*	0	0	0	*	-
D(1)	ESP	32.6	1.05	100	*	*	*	45	12	0.37	*	88
D(2)	ESP	26.3	0.78	64	*	*	*	15	4.2	0.16	*	93
F[a]	SCR[d]	51.6	1.86	491	162	-	-	<5	<5	<0.10	*	>99
1 Lime G	SCR		3.53	585	450	272	8.07	5	2.9	0.09	99	99.5
1 DBD[e]	SCR	23.4	2.96	350	347	179	7.65	15	7.8	0.33	96	98
2 Lime H 1 DBD	BH	171	2.97	1879	*	*	*	199	331	1.94	*	82

[a] From Dynascience continuous monitor.
[b] Baghouse.
[c] Electrostatic precipitator.
[d] Scrubber.
[e] Dead-burned dolomite.
*No inlet SO_2 levels were measured.

Table C-3. SUMMARY OF LIME KILN OFF-GAS VISIBLE EMISSIONS

Plant	B	C	D(1)	D(2)	E	F
Control Device	BH	ESP	ESP	ESP	BH	SCR
Percent Capacity	111	96	106	86	91	95
Number of six minute average opacities[1]	60	342	228	193	208	20
Percent of six minute averages with zero opacity	97	70	61	33	94	90
Maximum six minute average opacity	1.0	6.7	11.5[2]	5.8	4.6	0.4

[1] EPA Method 9 used for opacity readings

[2] This 6 minute average occurred because of an ESP malfunction for 2 minutes - next highest 6 minute average was 5.2 percent.

Table C-4
Summary of EPA Test Results
Plant B
Fuel - 0.6% S Coal
Control Equipment - Baghouse

Run No.[1]	1A	1B	2A	2B	3A	3B
Date	1/22/74	1/22/74	1/23/74	1/23/74	1/24/74	1/24/74
Test Time-Minutes	192	192	144	144	144	144
Stone Feed Rate-tons/hr	60		60		60	
Stack Effluent						
Flow Rate-ACFM	23,894	20,109	28,621	31,753	42,289	30,442
FLow Rate-DSCFM	13,241	16,973	11,081	22,481	15,718	16,206
Temperature-°F	362	372	352	358	372	378
Water Vapor-Vol %	14.3	16.4	15.6	18.0	14.6	16.7
CO_2-Vol % dry	16.6	17.8	19.4	18.7	19.0	18.8
O_2-Vol % dry	6.8	6.8	8.2	8.0	8.1	8.2
CO-Vol % dry	0	0	0	0	0	0
N_2 and other gases-Vol % dry	76.6	75.4	72.4	73.3	72.9	73.0
NO_x-ppm	216	275	198	288	179	267
SO_2-ppm	15	8	30	20	12	23
CO-ppm	20		10		10	
Particulate Emissions						
Probe and Filter Catch						
gr/DSCF	0.0204	0.0318	0.0209	0.0359	0.0210	0.0477
gr/ACF	0.0113	0.0268	0.0081	0.0254	0.0078	0.0253
lb/hr	2.318	4.622	1.982	6.923	2.783	6.623
lb/ton	0.039	0.077	0.033	0.115	0.046	0.110

Table C-4 (continued)

Total Catch						
gr/DSCF	0.0244	0.0353	0.0237	0.0407	0.0250	0.0505
gr/ACF	0.0135	0.0298	0.0092	0.0288	0.0093	0.0269
lb/hr	2.767	5.133	2.247	7.834	3.394	7.011
lb/ton	0.046	0.086	0.037	0.131	0.057	0.117

[1] Test data from two stacks of four.

Table C-5

Plant Personnel & EPA Test Results

Plant B
Fuel-0.6% S Coal
Control Equipment - Baghouse

	Plant Personnel Tests (Stacks C and D) Number of Tests	Plant Personnel Tests (Stacks C and D) Average Total Emission	EPA Tests (Stacks A and B) Number of Tests	EPA Tests (Stacks A and B) Average Total Emission	Average Total Plant Emissions
Stack Effluent	3		3		
Flow Rate-ACFM		74700		59000	133700
Flow Rate-DSCFM		40500		31900	72400
Temperature-°F		378		366	372
Water Vapor-Vol.%		14.6		15.9	15.3
CO_2-Vol.% dry		20.2		18.4	19.3
O_2-Vol.% dry		8.5		7.7	8.1
CO-Vol.% dry		0		0	0
N_2 and other gases-Vol.% dry		71.3		73.9	72.6
NO_x-ppm	5	54	6	236	145
SO_2-ppm	4	8	6	18	13
CO-ppm	3	10	3	13	12
Particulate Emissions	3		3		
Probe & Filter Catch					
gr/DSCF		0.014		0.030	0.022
gr/ACF		0.007		0.016	0.012
lb/hr		4.9		8.4	13.3
lb/ton[a]		-		-	0.22
Total Catch					
gr/DSCF		0.018		0.033	0.026
gr/ACF		0.010		0.018	0.014
lb/hr		6.2		9.5	15.7
lb/ton[a]		-		-	0.26

[a] Stone feed rate - 60 TPH

TABLE C-6

FACILITY B

Summary of Visible Emissions

Observer # 1

Date: 1/22/74

Type of Plant: Lime Kiln

Type of Discharge: Stack

Distance from Observer to Discharge Point: 75 ft.

Location of Discharge: Baghouse Outlet

Height of Observation Point: 70 ft.

Height of Point of Discharge: 100 ft.

Direction of Observer from Discharge Point: S

Description of Background: Hill: Brown

Description of Sky: Overcast

Wind Direction: Variable

Wind Velocity: 5-10 MPH

Color of Plume: None

Detached Plume: No

Duration of Observation: 60 min.

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1	1341	1346	0	0
2	1347	1352	0	0
3	1353	1358	0	0
4	1359	1404	0	0
5	1405	1410	0	0
6	1411	1416	0	0
7	1417	1422	0	0
8	1423	1428	0	0
9	1429	1434	0	0
10	1435	1440	0	0

TABLE C-7
FACILITY B
Summary of Visible Emissions
Observer # 2

Date: 1/22/74

Type of Plant: Lime Kiln

Type of Discharge: Stack

Distance from Observer to Discharge Point: 75 ft.

Location of Discharge: Baghouse Outlet

Height of Observation Point: 70 ft.

Height of Point of Discharge: 70 ft.

Direction of Observer from Discharge Point: S

Description of Background: Hill (Brown)

Description of Sky: Overcast

Wind Direction: Variable

Wind Velocity: 5-10 MPH

Color of Plume: None

Detached Plume: No

Duration of Observation: 60 min.

SUMMARY OF AVERAGE OPACITY

	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	1341	1346	0	0	21				
2	1347	1352	0	0	22				
3	1353	1358	0	0	23				
4	1359	1404	0	0	24				
5	1405	1410	0	0	25				
6	1411	1416	0	0	26				
7	1417	1422	0	0	27				
8	1423	1428	0	0	28				
9	1429	1434	0	0	29				
10	1435	1440	5	0.2	30				
11					31				
12					32				
13					33				
14					34				
15					35				
16					36				
17					37				
18					38				
19					39				
20					40				

TABLE C-8

FACILITY B

Summary of Visible Emissions

Obserber # 1

Date: 1/23/74

Type of Plant: Lime Kiln

Type of Discharge: Stack

Distance from Observer to Discharge Point: 100 Ft.

Location of Discharge: Baghouse Outlet

Height of Observation Point: 75 Ft.

Height of Point of Discharge: 75 Ft.

Direction of Observer from Discharge Point: S

Description of Background: Hill (brown)

Description of Sky: Partly Cloudy

Wind Direction: Variable

Wind Velocity: 5 MPH

Color of Plume: White

Detached Plume: No

Duration of Observation: 60 min.

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1	1042	1047	0	0
2	1048	1053	0	0
3	1054	1059	0	0
4	1100	1105	0	0
5	1106	1111	0	0
6	1112	1117	0	0
7	1118	1123	0	0
8	1124	1129	0	0
9	1130	1135	0	0
10	1136	1141	0	0
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				

TABLE C-9

FACILITY B

Summary of Visible Emissions

Observer # 2

Date: 1/23/74

Type of Plant: Lime Kiln

Type of Discharge: Stack

Distance from Observer to Discharge Point: 100 Ft.

Location of Discharge: Baghouse Outlet

Height of Observation Point: 75 Ft.

Height of Point of Discharge: 75 Ft.

Direction of Observer from Discharge Point: S

Description of Background: Hill (brown)

Description of Sky: Partly Cloudy

Wind Direction: Variable

Wind Velocity: 5 MPH

Color of Plume: White

Detached Plume: No

Duration of Observation: 60 Min.

SUMMARY OF AVERAGE OPACITY

	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	1042	1047	0	0	21				
2	1048	1053	0	0	22				
3	1054	1059	0	0	23				
4	1100	1105	0	0	24				
5	1106	1111	0	0	25				
6	1112	1117	0	0	26				
7	1118	1123	0	0	27				
8	1124	1129	0	0	28				
9	1130	1135	0	0	29				
10	1136	1141	0	0	30				
11					31				
12					32				
13					33				
14					34				
15					35				
16					36				
17					37				
18					38				
19					39				
20					40				

TABLE C-10

FACILITY B

Summary of Visible Emissions

Observer # 1

Date: 1/24/74

Type of Plant: Lime Kiln

Type of Discharge: Stack

Distance from Observer to Discharge Point: 100 Ft.

Location of Discharge: Baghouse Outlet

Height of Observation Point: 75 Ft.

Height of Point of Discharge: 75 Ft.

Direction of Observer from Discharge Point: S

Description of Background: Hill (brown)

Description of Sky: Partly Cloudy

Wind Direction: Variable

Wind Velocity: 5-10 MPH

Color of Plume: White

Detached Plume: No

Duration of Observation: 60 Min.

SUMMARY OF AVERAGE OPACITY

SUMMARY OF AVERAGE OPACITY

	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	916	921	0	0	21				
2	922	927	0	0	22				
3	928	933	0	0	23				
4	934	939	0	0	24				
5	940	945	0	0	25				
6	946	951	0	0	26				
7	952	957	0	0	27				
8	958	1003	25	1.0	28				
9	1004	1009	0	0	29				
10	1010	1015	0	0	30				
11					31				
12					32				
13					33				
14					34				
15					35				
16					36				
17					37				
18					38				
19					39				
20					40				

TABLE C-11
FACILITY B
Summary of Visible Emissions
Observer # 2

Date: 1/24/74

Type of Plant: Lime Kiln

Type of Discharge: Stack

Distance from Observer to Discharge Point: 100 Ft.

Location of Discharge: Baghouse Outlet

Height of Observation Point: 75 Ft.

Height of Point of Discharge: 75 Ft.

Direction of Observer from Discharge Point: S

Description of Background: Hill (brown)

Description of Sky: Partly Cloudy

Wind Direction: Variable

Wind Velocity: 5-10 MPH

Color of Plume: White

Detached Plume: No

Duration of Observation: 60 Min.

SUMMARY OF AVERAGE OPACITY					SUMMARY OF AVERAGE OPACITY				
	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	916	926	0	0	21				
2	922	927	0	0	22				
3	928	933	0	0	23				
4	934	939	0	0	24				
5	940	945	0	0	25				
6	946	951	0	0	26				
7	952	957	0	0	27				
8	958	1003	0	0	28				
9	1004	1009	0	0	29				
10	1010	1015	0	0	30				
11					31				
12					32				
13					33				
14					34				
15					35				
16					36				
17					37				
18					38				
19					39				
20					40				

Table C-12
Summary of Test Results

Plant C
Fuel - Gas
Control Equipment - Electrostatic Precipitator

Run No.	1(1)	2(1)	3(1)	Average
Date	4/30/74	5/2/74	5/3-4/74	---
Test Time-Minutes	126	200	200	175
Stone Feed Rate-tons/hr	40.6	40.0	40.6	40.4
Stack Effluent				
Flow Rate-ACFM	191,429	170,711	179,451	180,530
Flow Rate-DSCFM	96,978	88,856	92,011	92,615
Temperature-°F	411	386	385	394
Water Vapor-Vol.%	17.8	17.7	18.4	18.0
CO_2-Vol.% dry	9.4	10.1	9.1	9.5
O_2-Vol.% dry	11.6	10.5	10.2	10.8
CO-Vol.% dry	0	0	0	0
N_2 and other gases-Vol.% dry	79.0	79.4	80.7	79.7
NO_x-ppm	129	96	96	107
SO_2-ppm	0	0	0	0
CO-ppm	41	54	255	117
Particulate Emissions				
Probe & Filter Catch				
gr/DSCF	0.0114	0.0031	0.0058	0.0068
gr/ACF	0.0058	0.0016	0.0030	0.0035
lb/hr	9.51	2.37	4.55	5.466
lb/ton	0.234	0.0591	0.1118	0.135
Total Catch				
gr/DSCF	0.0200	0.0101	0.0101	0.0134
gr/ACF	0.0101	0.0053	0.0052	0.0069
lb/hr	16.68	7.73	8.0	10.8
lb/ton	0.411	0.193	0.197	0.267

(1) Test data from two stacks.

TABLE C-13

FACILITY C

Summary of Visible Emissions

Observer: 1

Date: 30 April 1974

Type of Plant: Lime Kiln

Type of Discharge: ESP Outlet

Location of Discharge: South Stack

Height of Point of Discharge: 100 Ft.

Distance from Observer to Discharge Point: 525 Ft.

Height of Observation Point: 0 Ft.

Direction of Observer from Discharge Point: SW

Description of Background: White-gray clouds

Description of Sky: Overcast

Wind Direction: SE

Wind Velocity: 6-10 MPH

Color of Plume: None

Detached Plume: None

Duration of Observation:

SUMMARY OF AVERAGE OPACITY

	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	1605	1611	0	0	21	1805	1811	0	0
2	1611	1617	0	0	22	1811	1817	0	0
3	1617	1623	0	0	23	1817	1823	0	0
4	1623	1629	0	0	24	1823	1829	0	0
5	1629	1635	0	0	25	1829	1835	0	0
6	1635	1641	0	0	26	1835	1841	0	0
7	1641	1647	0	0	27	1841	1847	0	0
8	1647	1653	0	0	28	1847	1853	0	0
9	1653	1659	0	0	29				
10	1659	1705	0	0	30				
11	1705	1711	0	0	31				
12	1711	1717	0	0	32				
13	1717	1723	0	0	33				
14	1723	1729	0	0	34				
15	1729	1735	0	0	35				
16	1735	1741	0	0	36				
17	1741	1747	0	0	37				
18	1747	1753	0	0	38				
19	1753	1759	0	0	39				
20	1759	1805	0	0	40				

TABLE C-14

FACILITY C

Summary of Visible Emissions

Observer : 2

Date: 30 April 1974

Type of Plant: Lime Kiln

Type of Discharge: ESP Outlet

Distance from Observer to Discharge Point: 525 Ft.

Location of Discharge: South Stack

Height of Observation Point: 0 Ft.

Height of Point of Discharge: 100 Ft.

Direction of Observer from Discharge Point: SW

Description of Background: white-gray clouds

Description of Sky: Overcast

Wind Direction: SE

Wind Velocity: 6-10 MPH

Color of Plume: None

Detached Plume: None

Duration of Observation:

SUMMARY OF AVERAGE OPACITY					SUMMARY OF AVERAGE OPACITY				
	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	1605	1611	0	0	21	1805	1811	0	0
2	1611	1617	0	0	22	1811	1817	0	0
3	1617	1623	0	0	23	1817	1823	0	0
4	1623	1629	0	0	24	1823	1829	0	0
5	1629	1635	0	0	25	1829	1835	0	0
6	1635	1641	0	0	26	1835	1841	0	0
7	1641	1647	0	0	27	1841	1847	0	0
8	1647	1653	0	0	28	1847	1853	0	0
9	1653	1659	0	0	29				
10	1659	1705	0	0	30				
11	1705	1711	0	0	31				
12	1711	1717	0	0	32				
13	1717	1723	0	0	33				
14	1723	1729	0	0	34				
15	1729	1735	0	0	35				
16	1735	1741	0	0	36				
17	1741	1747	0	0	37				
18	1747	1753	0	0	38				
19	1753	1759	0	0	39				
20	1759	1805	0	0	40				

TABLE C-15

FACILITY C

Summary of Visible Emissions

Observer: 3

Date: 30 April 1974

Type of Plant: Lime Kiln

Type of Discharge: ESP Outlet

Distance from Observer to Discharge Point: 525 Ft.

Location of Discharge: North Stack

Height of Observation Point: 0 Ft.

Height of Point of Discharge: 100 Ft.

Direction of Observer from Discharge Point: SW

Description of Background: white-gray clouds

Description of Sky: Overcast

Wind Direction: SE

Wind Velocity: 6-10 MPH

Color of Plume: None

Detached Plume: None

Duration of Observation:

SUMMARY OF AVERAGE OPACITY

Set Number	Time Start	Time End	Opacity Sum	Opacity Average
1	1605	1611	0	0
2	1611	1617	0	0
3	1617	1623	0	0
4	1623	1629	0	0
5	1629	1635	0	0
6	1635	1641	0	0
7	1641	1647	0	0
8	1647	1653	0	0
9	1653	1659	0	0
10	1659	1705	0	0
11	1705	1711	0	0
12	1711	1717	0	0
13	1717	1723	0	0
14	1723	1729	0	0
15	1729	1735	0	0
16	1735	1741	0	0
17	1741	1747	0	0
18	1747	1753	0	0
19	1753	1759	0	0
20	1759	1805	0	0

SUMMARY OF AVERAGE OPACITY

Set Number	Time Start	Time End	Opacity Sum	Opacity Average
21	1805	1811	0	0
22	1811	1817	0	0
23	1817	1823	0	0
24	1823	1829	0	0
25	1829	1835	0	0
26	1835	1841	0	0
27	1841	1847	0	0
28	1847	1853	0	0
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				

TABLE C-16

FACILITY C

Summary of Visible Emissions

Observer: 4

Date: 30 April 1974

Type of Plant: Lime Kiln

Type of Discharge: ESP Outlet

Distance from Observer to Discharge Point: 525 Ft.

Location of Discharge: North Stack

Height of Observation Point: 0 Ft.

Height of Point of Discharge: 100 Ft.

Direction of Observer from Discharge Point: SW

Description of Background: white-gray clouds

Description of Sky: Overcast

Wind Direction: SE

Wind Velocity: 6-10 MPH

Color of Plume: None

Detached Plume: None

Duration of Observation:

SUMMARY OF AVERAGE OPACITY					SUMMARY OF AVERAGE OPACITY				
	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	1605	1611	0	0	21	1808	1814	0	0
2	1611	1617	0	0	22	1814	1820	0	0
3	1617	1623	0	0	23	1820	1826	0	0
4	1623	1629	0	0	24	1826	1832	0	0
5	1629	1635	0	0	25	1832	1838	0	0
6	1635	1641	0	0	26	1838	1844	0	0
7	1641	1647	0	0	27	1844	1850	0	0
8	1647	1653	0	0	28	1850	1856	0	0
9	1653	1659	0	0	29				
10	1659	1705	0	0	30				
11	1705	1711	0	0	31				
12	1711	1717	0	0	32				
13	1717	1723	0	0	33				
14	1723	1729	0	0	34				
15	1729	1735	0	0	35				
16	1736	1742	0	0	36				
17	1742	1748	0	0	37				
18	1748	1754	0	0	38				
19	1754	1800	0	0	39				
20	1800	1806	0	0	40				

TABLE C-17
FACILITY C
Summary of Visible Emissions
Observer: 1

Date: 2 May 1974

Type of Plant: Lime Kiln

Type of Discharge: ESP Outlet

Distance from Observer to Discharge Point: 525 Ft.

Location of Discharge: South Stack

Height of Observation Point: 0 Ft.

Height of Point of Discharge: 100 Ft.

Direction of Observer from Discharge Point: SW

Description of Background: Scattered clouds

Description of Sky: Partly cloudy Blue/white

Wind Direction: S-SW

Wind Velocity: 4-6 MPH

Color of Plume: None

Detached Plume: None

Duration of Observation:

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1	1152	1158	0	0
2	1158	1204	0	0
3	1204	1210	0	0
4	1210	1216	0	0
5	1216	1222	0	0
6	1222	1228	0	0
7	1228	1234	0	0
8	1234	1240	0	0
9	1240	1246	0	0
10	1246	1252	0	0
11	1252	1258	0	0
12	1258	1304	0	0
13	1304	1310	0	0
14	1310	1316	0	0
15	1316	1322	0	0
16	1322	1328	0	0
17	1328	1334	0	0
18	1334	1340	0	0
19	1340	1346	0	0
20	1346	1352	0	0

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
21	1352	1358	0	0
22	1358	1404	0	0
23	1404	1410	0	0
24	1410	1416	0	0
25	1416	1422	0	0
26	1422	1428	0	0
27	1428	1434	0	0
28	1434	1440	0	0
29	1440	1446	0	0
30	1446	1452	0	0
31	1452	1458	0	0
32	1458	1504	0	0
33	1504	1510	0	0
34	1510	1516	0	0
35	1516	1522	0	0
36	1522	1528	0	0
37	1528	1534	0	0
38	1534	1540	0	0
39	1540	1546	0	0
40	1546	1552	0	0

TABLE C-18
FACILITY C
Summary of Visible Emissions
Observer: 2

Date: 2 May 1974

Type of Plant: Lime Kiln

Type of Discharge: ESP Outlet

Distance from Observer to Discharge Point: 525 Ft.

Location of Discharge: South Stack

Height of Observation Point: 0 Ft.

Height of Point of Discharge: 100 Ft.

Direction of Observer from Discharge Point: SW

Description of Background: Scattered Clouds

Description of Sky: Partly Cloudy Blue/White

Wind Direction: S-SW

Wind Velocity: 4-10 MPH

Color of Plume: None

Detached Plume: None

Duration of Observation:

SUMMARY OF AVERAGE OPACITY

	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	1352	1358	0	0	21				
2	1358	1404	0	0	22				
3	1404	1410	0	0	23				
4	1410	1416	0	0	24				
5	1416	1422	0	0	25				
6	1422	1428	0	0	26				
7	1428	1434	0	0	27				
8	1434	1440	0	0	28				
9	1440	1446	0	0	29				
10	1446	1452	0	0	30				
11	1452	1458	0	0	31				
12	1458	1504	0	0	32				
13	1504	1510	0	0	33				
14	1510	1516	0	0	34				
15	1516	1522	0	0	35				
16	1522	1528	0	0	36				
17	1528	1534	0	0	37				
18	1534	1540	0	0	38				
19	1540	1546	0	0	39				
20	1546	1552	0	0	40				

TABLE C-19

FACILITY C

Summary of Visible Emissions

Observer: 2

Date: 2 May 1974

Type of Plant: Lime Kiln

Type of Discharge: ESP Outlet

Distance from Observer to Discharge Point: 525 Ft.

Location of Discharge: North Stack

Height of Observation Point: 0 Ft.

Height of Point of Discharge: 100 Ft.

Direction of Observer from Discharge Point: SW

Description of Background: Scattered Clouds

Description of Sky: Partly Cloudy Blue/White

Wind Direction: S-SW

Wind Velocity: 4-6 MPH

Color of Plume: None

Detached Plume: None

Duration of Observation:

SUMMARY OF AVERAGE OPACITY | SUMMARY OF AVERAGE OPACITY

	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	1152	1158	0	0	21				
2	1158	1204	0	0	22				
3	1204	1210	0	0	23				
4	1210	1216	0	0	24				
5	1216	1222	0	0	25				
6	1222	1228	0	0					
7	1228	1234	0	0					
8	1234	1240	0	0	28				
9	1240	1246	0	0	29				
10	1246	1252	0	0	30				
11	1252	1258	0	0	31				
12	1258	1304	0	0	32				
13	1304	1310	0	0	33				
14	1310	1316	0	0	34				
15	1316	1322	0	0	35				
16	1322	1328	0	0	36				
17	1328	1334	0	0	37				
18	1334	1340	0	0	38				
19	1340	1346	0	0	39				
20	1346	1352	0	0	40				

TABLE C-20

FACILITY C

Summary of Visible Emissions

Observer: 4

Date: 2 May 1974

Type of Plant: Lime Kiln

Type of Discharge: ESP Outlet

Distance from Observer to Discharge Point: 525 Ft.

Location of Discharge: North Stack

Height of Observation Point: 0 Ft.

Height of Point of Discharge: 100 Ft.

Direction of Observer from Discharge Point: SW

Description of Background: Sky

Description of Sky: Partly Cloudy Blue/white/grey

Wind Direction: S-SW

Wind Velocity: 4-6 MPH

Color of Plume: None

Detached Plume: None

Duration of Observation:

SUMMARY OF AVERAGE OPACITY

Set Number	Time Start	Time End	Opacity Sum	Opacity Average
1	1152	1158	0	0
2	1158	1204	0	0
3	1204	1210	0	0
4	1210	1216	0	0
5	1216	1222	0	0
6	1222	1228	0	0
7	1228	1234	0	0
8	1234	1240	0	0
9	1240	1246	0	0
10	1246	1252	0	0
11	1252	1258	0	0
12	1258	1304	20	0.8
13	1304	1310	120	5.0
14	1310	1316	120	5.0
15	1316	1322	120	5.0
16	1322	1328	110	4.6
17	1328	1334	120	5.0
18	1334	1340	120	5.0
19	1340	1346	120	5.0
20	1346	1352	120	5.0
21	1352	1358	115	4.8
22	1358	1404	120	5.0
23	1404	1410	120	5.0
24	1410	1416	120	5.0
25	1416	1422	120	5.0
26	1422	1428	120	5.0
27	1428	1434	120	5.0
28	1434	1440	120	5.0
29	1440	1446	120	5.0
30	1446	1452	120	5.0
31	1452	1458	115	4.8
32	1458	1504	120	5.0
33	1504	1510	120	5.0
34	1510	1516	120	5.0
35	1516	1522	120	5.0
36	1522	1528	115	4.8
37	1528	1534	120	4.8
38	1534	1540	120	4.8
39	1540	1546	120	4.8
40	1546	1552	120	4.8

Note: Sets 12 thru 40, Observer reported all readings as either "0" or "less than 5%". For purposes of this summary, the latter was considered as "5 percent".

TABLE C-21

FACILITY C

Summary of Visible Emissions

Observer:1

Date: 3 May 1974

Type of Plant: Lime Kilns

Type of Discharge: ESP Outlet

Distance from Observer to Discharge Point: 450 ft.

Location of Discharge: South Stack

Height of Observation Point: 0 ft.

Height of Point of Discharge: 100 ft.

Direction of Observer from Discharge Point: NE

Description of Background: Sky

Description of Sky: Partly cloudy, Hazy Blue

Wind Direction: S-SE

Wind Velocity: 5-10 mph

Color of Plume: Yellowish

Detached Plume: none

Duration of Observation:

SUMMARY OF AVERAGE OPACITY					SUMMARY OF AVERAGE OPACITY				
	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	10:10	10:16	35	1.5	21				
2	10:16	10:22	20	0.8	22				
3	10:22	10:28	0	0	23				
4	10:28	10:34	0	0	24				
5	10:34	10:40	0	0	25				
6	10:40	10:46	0	0	26				
7	10:46	10:52	0	0	27				
8	10:52	10:58	0	0	28				
9	10:58	11:04	0	0	29				
10	11:04	11:10	0	0	30				
11	11:10	11:16	0	0	31				
12	11:16	11:22	0	0	32				
13	11:22	11:28	0	0	33				
14	11:28	11:34	0	0	34				
15	11:34	11:40	0	0	35				
16	11:40	11:46	0	0	36				
17	11:46	11:52	0	0	37				
18	11:52	11:56	0	0	38				
19	11:56	12:04	0	0	39				
20	12:04	12:10	0	0	40				

TABLE C-22
FACILITY C
Summary of Visible Emissions
Observer: 4

Date: 3 May 1974

Type of Plant: Lime Kiln

Type of Discharge: ESP outlet

Distance from Observer to Discharge Point: 450 ft

Location of Discharge: South Stack

Height of Observation Point: 0 ft.

Height of Point of Discharge: 100 ft.

Direction of Observer from Discharge Point: NE

Description of Background: sky

Description of Sky: partly cloudy

Wind Direction: S-SE

Wind Velocity: 10-15 mph

Color of Plume: White

Detached Plume: no

Duration of Observation:

SUMMARY OF AVERAGE OPACITY | SUMMARY OF AVERAGE OPACITY

	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	10:09	10:15	160	6.7	21	12:09	12:15	120	5
2	10:15	10:21	135	5.6	22	12:15	12:21	120	5
3	10:21	10:27	120	5.0	23	12:21	12:27	120	5
4	10:27	10:33	120	5	24	12:27	12:33	120	5
5	10:33	10:39	120	5	25	12:33	12:39	120	5
6	10:39	10:45	120	5	26	12:39	12:45	120	5
7	10:45	10:51	120	5	27	12:45	12:51	120	5
8	10:51	10:57	120	5	28	12:51	12:57	120	5
9	10:57	11:03	120	5	29	12:57	13:03	120	5
10	11:03	11:09	120	5	30	13:03	13:09	120	5
11	11:09	11:15	120	5	31	13:09	13:15	120	5
12	11:15	11:21	120	5	32	13:15	13:21	120	5
13	11:21	11:27	120	5	33	13:21	13:27	120	5
14	11:27	11:33	120	5	34	13:27	13:33	120	5
15	11:33	11:39	120	5	35	13:33	13:39	120	5
16	11:39	11:45	120	5	36				
17	11:45	11:51	120	5	37				
18	11:51	11:57	120	5	38				
19	11:57	12:03	120	5	39				
20	12:03	12:09	120	5	40				

Note: Observer reported readings of "less than 5 %" have been considered as "5%" in this summary

TABLE C-23

FACILITY C

Summary of Visible Emissions

Observer: 1

Date: 3 May 1974

Type of Plant: Lime Kiln

Type of Discharge: ESP outlet

Distance from Observer to Discharge Point: 450 ft.

Location of Discharge: north stack

Height of Observation Point: 0 ft.

Height of Point of Discharge: 100 ft.

Direction of Observer from Discharge Point: NE

Description of Background: sky

Description of Sky: Partly cloudy; hazy blue

Wind Direction: S-SE

Wind Velocity: 5-10 mph

Color of Plume: Yellowish

Detached Plume: none

Duration of Observation:

SUMMARY OF AVERAGE OPACITY					SUMMARY OF AVERAGE OPACITY				
	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	10:10	10:16	35	1.5	21				
2	10:16	10:22	5	0.2	22				
3	10:22	10:28	0	0	23				
4	10:28	10:34	0	0	24				
5	10:34	10:40	0	0	25				
6	10:40	10:46	0	0	26				
7	10:46	10:52	0	0	27				
8	10:52	10:58	0	0	28				
9	10:58	11:04	0	0	29				
10	11:04	11:10	0	0	30				
11	11:10	11:16	0	0	31				
12	11:16	11:22	0	0	32				
13	11:22	11:28	0	0	33				
14	11:28	11:34	0	0	34				
15	11:34	11:40	0	0	35				
16	11:40	11:46	0	0	36				
17	11:46	11:52	0	0	37				
18	11:52	11:58	0	0	38				
19	11:58	12:04	0	0	39				
20	12:04	12:10	0	0	40				

TABLE C-24

FACILITY C

Summary of Visible Emissions
Observer: 4

Date: 3 May 1974

Type of Plant: Lime Kiln

Type of Discharge: ESP Outlet

Distance from Observer to Discharge Point: 450 Ft.

Location of Discharge: North Stack

Height of Observation Point: 0 Ft.

Height of Point of Discharge: 100 Ft.

Direction of Observer from Discharge Point: NE

Description of Background: Sky

Description of Sky: partly cloudy

Wind Direction: S-SE

Wind Velocity: 10-15 MPH

Color of Plume: White

Detached Plume: No

Duration of Observation:

SUMMARY OF AVERAGE OPACITY					SUMMARY OF AVERAGE OPACITY				
	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	1009	1015	135	5.8	21	1209	1215	120	5
2	1015	1021	130	5.4	22	1215	1221	120	5
3	1021	1027	120	5.0	23	1221	1227	120	5
4	1027	1033	120	5	24	1227	1233	120	5
5	1033	1039	120	5	25	1233	1239	120	5
6	1039	1045	120	5	26	1239	1245	120	5
7	1045	1051	120	5	27	1245	1251	120	5
8	1051	1057	120	5	28	1251	1257	120	5
9	1057	1103	120	5	29	1257	1303	120	5
10	1103	1109	120	5	30	1303	1309	120	5
11	1109	1115	120	5	31	1309	1315	120	5
12	1115	1121	120	5	32	1315	1321	120	5
13	1121	1127	120	5	33	1321	1327	120	5
14	1127	1133	120	5	34	1327	1333	120	5
15	1133	1139	120	5	35	1333	1339	120	5
16	1139	1145	120	5	36				
17	1145	1151	120	5	37				
18	1151	1157	120	5	38				
19	1157	1203	120	5	39				
20	1203	1209	120	5	40				

Note: Observer reported readings of "less than 5%" have been considered as "5%" in this summary.

Table C-25
Summary of Test Results
Plant D(1)
Fuel - Gas & Oil (1.05% S)
Control Equipment - Electrostatic Precipitator

Run No.	1*	3	5	Average
Date	7/8/74	7/9/74	7/10/74	-
Test Time-Minutes	240	240	240	240
Stone Feed Rate-tons/hr	32.7	32.5	32.6	32.6
Stack Effluent				
Flow Rate-ACFM	64,390	67,300	70,330	68,800
Flow Rate-DSCFM	27,620	27,390	28,660	28,000
Temperature-°F	621	669	674	672
Water Vapor-Vol.%	11.3	12.1	11.4	11.8
CO_2-Vol.% dry	21.7	21.0	19.6	20.3
O_2-Vol.% dry	8.0	8.7	11.4	10.0
CO-Vol.% dry	0	0	0	0
N_2 and other gases-Vol.% dry	70.3	70.3	69.0	69.7
NO_x-ppm	299	340	380	340
SO_2-ppm	70	11	53	45
Particulate Emissions				
Probe and Filter Catch				
gr/DSCF	0.051	0.046	0.026	0.036
gr/ACF	0.022	0.019	0.011	0.015
lb/hr	12.0	10.9	6.4	8.7
lb/ton	0.367	0.335	0.196	0.266
Total Catch				
gr/DSCF	0.111	0.064	0.055	0.060
gr/ACF	0.047	0.026	0.022	0.024
lb/hr	26.2	15.0	13.6	14.3
lb/ton	0.802	0.462	0.417	0.439

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*Particulate test data questionable - not used in averages.

TABLE C-26

FACILITY D

Summary of Visible Emissions

Date: 7-8-74

Type of Plant: Lime

Type of Discharge: Stack

Location of Discharge: ESP

Height of Point of Discharge: 110

Description of Background: Sky

Description of Sky: Partly Cloudy

Wind Direction:

Color of Plume: White

Duration of Observation: 228 min.

Distance from Observer to Discharge Point: 200 Ft.

Height of Observation Point: 100 Ft.

Direction of Observer from Discharge Point: NW

Wind Velocity:

Detached Plume: No

Observer No. 2

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1	1713	1718	0	0
2	1719	1724	30	1.2
3	1725	1730	75	3.1
4	1731	1736	55	2.3
5	1737	1742	70	2.9
6	1743	1748	55	2.3
7	1749	1754	30	1.2
8	1755	1800	115	4.8
9	1801	1806	5	0.2
10	1807	1812	30	1.3
11	1813	1818	125	5.2
12	1819	1824	120	5
13	1825	1830	60	2.5
14	1831	1836	35	1.5
15	1837	1842	15	0.6
16	1843	1848	5	0.2
17	1849	1854	5	0.2
18-34	1855	2049	0	0
35	2050	2055	20	0.8
36	2056	2101	100	4.2
37	2102	2103	0	0

TABLE C- 27

FACILITY D

Summary of Visible Emissions

Date: 7-8-74

Type of Plant: Lime

Type of Discharge: Stack

Location of Discharge: ESP

Height of Point of Discharge: 110 Ft.

Description of Background: Sky

Description of Sky: Partly Cloudy

Wind Direction:

Color of Plume: White

Duration of Observation: 247 min.

Distance from Observer to Discharge Point: 250 Ft.

Height of Observation Point: 100 Ft.

Direction of Observer from Discharge Point: NW

Wind Velocity:

Detached Plume: No

Observer No. 1

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1-18	1715	1902	0	0
19	1903	1908	5	0.2
20	1908	1914	5	0.2
21-24	1915	1939	0	0
25	1939	1944	5	0.2
26-39	1945	2108	0	0
40	2109	2114	275	11.5
41	2115	2120	0	0
42	2121	2123	0	0

TABLE C-28

FACILITY D

Summary of Visible Emissions

Date: 7-9-74

Type of Plant: Lime

Type of Discharge: Stack

Location of Discharge: ESP

Height of Point of Discharge: 110 Ft.

Description of Background: Sky

Description of Sky: Light Blue

Wind Direction:

Color of Plume: White

Duration of Observation: 245 Min.

Distance from Observer to Discharge Point: 200 Ft.

Height of Observation Point: 50 Ft.

Direction of Observer from Discharge Point: ESE

Wind Velocity:

Detached Plume: No

Observer No. 1

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1-8	840	927	0	0
9	928	933	15	0.6
10-16	934	1015	0	0
17	1016	1021	15	0.6
18	1022	1027	0	0
19	1028	1033	30	1.2
20	1034	1039	0	0
21	1040	1045	20	0.8
22	1046	1051	0	0
23	1052	1057	15	0.6
24	1058	1103	0	0
25	1104	1109	35	1.5
26	1110	1115	15	0.6
27	1116	1121	15	0.6
28	1122	1127	15	0.6
29	1128	1133	60	2.5
30	1134	1139	5	0.2
31	1140	1145	20	0.8
32	1146	1151	15	0.6
33	1152	1157	0	0

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
34	1158	1203	40	1.7
35	1204	1209	45	1.9
36	1210	1215	40	1.7
37	1216	1221	40	1.7
38	1222	1227	20	0.8
39	1228	1233	15	0.6
40	1234	1239	35	1.5
41	1240	1245	30	1.2

TABLE C-29

FACILITY D

Summary of Visible Emissions

Date: 7-9-74

Type of Plant: Lime

Type of Discharge: Stack

Location of Discharge: ESP

Height of Point of Discharge: 100 Ft.

Description of Background: Sky

Description of Sky: Hazy Blue

Wind Direction: NW

Color of Plume: White

Duration of Observation: 195 Min.

Distance from Observer to Discharge Point: 200 Ft.

Height of Observation Point: 0 Ft.

Direction of Observer from Discharge Point: NW

Wind Velocity: 3 MPH

Detached Plume: No

Observer No. 2

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1	843	848	80	3.3
2	849	854	55	2.3
3*	855	900	50	2.5
4*	901	906	45	4.5
5	907	912	80	3.3
6	913	918	75	3.1
7*	919	924	70	3.5
8*	925	930	85	5.3
9	931	936	85	3.5
10	937	942	40	1.7
11	943	948	115	4.8
12	949	954	65	2.7
13*	955	1000	35	2.9
14*	1001	1006	-	-
15*	1007	1012	105	5.2
16	1013	1018	115	4.8
17	1019	1024	100	4.2
18	1025	1030	100	4.2
19	1031	1036	120	5.0
20	1057	1102	105	4.4

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
21	1103	1108	105	4.4
22	1109	1114	95	4.0
23	1115	1120	95	4.0
24	1121	1126	95	4.0
25*	1127	1132	75	3.7
26*	1133	1138	-	-
27*	1139	1144	-	-
28*	1145	1150	85	5.5
29	1151	1156	120	5.0
30	1157	1202	105	4.4
31	1203	1208	120	5
32	1209	1214	120	5
33	1215	1220	120	5
34	1221	1226	120	5
35	1227	1232	30	1.2
36	1233	1238	90	3.8
37	1239	1244	80	3.3
38*	1245	1249	40	2.5

*Not complete 6 min. average.

TABLE C-30

FACILITY D

Summary of Visible Emissions

Date: 7-10-74

Type of Plant: Lime

Type of Discharge: Stack

Location of Discharge: ESP

Height of Point of Discharge: 110 Ft.

Description of Background: Sky

Description of Sky: Overcast

Wind Direction: N

Color of Plume: White

Duration of Observation: 272 Min.

Distance from Observer to Discharge Point: 200 Ft.

Height of Observation Point: 50 Ft.

Direction of Observer from Discharge Point: ESE

Wind Velocity: ~ nil

Detached Plume: No

Observer No. 1

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1-20	890	1019	0	0
21	1020	1025	10	0.4
22	1026	1031	5	0.2
23	1032	1037	0	0
24	1038	1043	20	0.8
25	1044	1049	0	0
26	1050	1055	25	1.0
27	1056	1101	5	0.2
28	1102	1107	35	1.4
29	1108	1113	20	0.8
30	1114	1119	10	0.4
31	1120	1125	10	0.4
32	1126	1131	0	0
33	1132	1137	20	0.8
34	1138	1143	0	0
35	1144	1149	10	0.4
36-45	1150	1249	0	0
46	1250	1252	0	0

TABLE C-31
FACILITY D
Summary of Visible Emissions

Date: 7-10-74

Type of Plant: Lime

Type of Discharge: Stack

Location of Discharge: ESP

Height of Point of Discharge: 110 Ft.

Description of Background: Sky

Description of Sky: Overcast

Wind Direction:

Color of Plume: White

Duration of Observation: 212 Min.

Distance from Observer to Discharge Point: 200 Ft.

Height of Observation Point: 0 Ft.

Direction of Observer from Discharge Point: NE

Wind Velocity:

Detached Plume: No

Observer No. 2

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1	838	843	25	1.0
2	844	849	30	1.2
3	850	855	70	2.9
4	856	858	0	0
5	937	942	85	3.5
6	943	948	10	0.4
7-10	949	1012	0	0
11	1013	1018	20	0.8
12-23	1019	1130	0	0
24	1131	1136	20	0.8
25	1137	1142	20	0.8
26-27	1143	1154	0	0
28	1155	1200	35	1.5
29	1201	1206	45	1.9
30-36	1207	1249	0	0

Table C-32
Summary of Test Results
Plant D
Fuel - Gas & Oil(0.78% S)
Control Equipment - Electrostatic Precipitator

Run No.	1	2	3	Average
Date	8/6/74	8/7/74	8/8/74	---
Test Time-Minutes	192	192	192	192
Stone Feed Rate-tons/hr	26.3	26.3	26.4	26.3
Stack Effluent				
Flow Rate-ACFM	65,320	66,488	65,754	65,854
Flow Rate-DSCFM	28,986	27,704	27,559	28,083
Temperature-°F	611	661	655	642
Water Vapor-Vol %	9.6	11.1	10.8	10.5
CO_2-Vol % dry	19.0	22.0	21.0	20.7
O_2-Vol % dry	8.7	6.1	7.0	7.3
CO-Vol % dry	0	0	0	0
N_2 and other gases-Vol % dry	72.3	71.9	72.0	72.0
NO_x-ppm	201	363	274	279
SO_2-ppm	6	27	13	15.3
CO-ppm				
Particulate Emissions				
Probe and Filter Catch				
gr/DSCF	0.0615	0.0143	0.0152	0.0303
gr/ACF	0.0273	0.0060	0.0064	0.0129
lb/hr	15.273	3.398	3.591	7.42
lb/ton	0.580	0.129	0.136	0.282

Table C-32 (continued)

Total Catch				
gr/DSCF	0.0971	0.0304	0.0225	0.0500
gr/ACF	0.0431	0.0127	0.0094	0.0213
lb/hr	24.118	7.226	5.312	12.219
lb/ton	0.918	0.275	0.201	0.465

TABLE C-33

FACILITY D

Summary of Visible Emissions

Observer # 1

Date: 8/6/74

Type of Plant: Lime Kiln

Type of Discharge: Stack

Distance from Observer to Discharge Point: ~ 100 Ft.

Location of Discharge: ESP # 1

Height of Observation Point: ~ 70 Ft.

Height of Point of Discharge: ~ 90 Ft.

Direction of Observer from Discharge Point: East

Description of Background: Sky

Description of Sky: 30% clouds against blue sky

Wind Direction: SW

Wind Velocity: 5-15 MPH

Color of Plume: White

Detached Plume: No.

Duration of Observation: 197 Min.

SUMMARY OF AVERAGE OPACITY — SUMMARY OF AVERAGE OPACITY

	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	1525	1530	60	2.5	21	1804	1809	115	4.8
2	1531	1536	55	2.3	22	1810	1815	95	4.0
3	1537	1542	35	1.5	23	1816	1821	0	0.0
4	1543	1548	85	3.5	24	1822	1827	5	0.2
5	1549	1554	70	2.9	25	1828	1833	55	2.3
6	1555	1600	85	3.5	26	1842	1847	20	0.8
7	1601	1606	75	3.1	27	1848	1853	25	1.0
8	1607	1612	5	0.2	28	1854	1859	35	1.5
9	1613	1618	5	0.2	29	1900	1905	80	3.3
10	1636	1641	0	0.0	30	1906	1911	0	0.0
11	1642	1647	0	0.0	31	1912	1917	20	0.8
12	1648	1653	0	0.0	32	1918	1923	70	2.9
13	1654	1659	0	0.0	33				
14	1700	1705	0	0.0	34				
15	1706	1711	0	0.0	35				
16	1712	1717	0	0.0	36				
17	1740	1745	20	0.8	37				
18	1746	1751	20	0.8	38				
19	1752	1757	120	5.0	39				
20	1758	1803	100	4.2	40				

TABLE C-34

FACILITY D

Summary of Visible Emissions

Observer # 2

Date: 8/6/74

Type of Plant: Lime Kiln

Type of Discharge: Stack

Distance from Observer to Discharge Point: 100 Ft.

Location of Discharge: ESP # 1

Height of Observation Point: 75 Ft.

Height of Point of Discharge: 80 Ft.

Direction of Observer from Discharge Point: SE

Description of Background: Sky

Description of Sky: Partly Cloudy (grey to blue)

Wind Direction: SW

Wind Velocity: 5-15 MPH

Color of Plume. White

Detached Plume: No

Duration of Observation: 213 Min.

SUMMARY OF AVERAGE OPACITY | SUMMARY OF AVERAGE OPACITY

	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	1525	1530	125	5.2	21	1746	1751	30	1.3
2	1531	1536	120	5.0	22	1752	1757	70	2.9
3	1537	1542	125	5.2	23	1758	1803	125	5.2
4	1543	1548	125	5.2	24	1804	1809	140	5.8
5	1549	1554	130	5.4	25	1810	1815	135	5.6
6	1555	1600	120	5.0	26	1816	1821	120	5.0
7	1601	1606	120	5.0	27	1822	1827	30	1.3
8	1607	1612	130	5.4	28	1828	1833	80	3.3
9	1613	1618	130	5.4	29	1842	1847	45	1.9
10	1619	1624	125	5.2	30	1848	1853	40	1.7
11	1625	1630	120	5.0	31	1854	1859	75	3.1
12	1631	1636	105	4.4	32	1900	1905	100	4.2
13	1637	1642	120	5.0	33	1906	1911	80	3.3
14	1643	1648	115	4.8	34	1912	1917	75	3.1
15	1649	1654	90	3.8	35	1918	1923	60	2.5
16	1655	1700	120	5.0	36				
17	1701	1706	100	4.2	37				
18	1707	1712	70	2.9	38				
19	1713	1718	45	1.9	39				
20	1740	1745	120	5.0	40				

TABLE C-35

FACILITY D

Summary of Visible Emissions

Observer # 1

Date: 8/7/74

Type of Plant: Lime Kiln

Type of Discharge: Stack

Distance from Observer to Discharge Point: ~100 Ft.

Location of Discharge: ESP # 1

Height of Observation Point: ~ 70 Ft.

Height of Point of Discharge: 80 Ft.

Direction of Observer from Discharge Point: E at start, moved to W at 13:20

Description of Background: Sky

Description of Sky: Hazy

Wind Direction: S-SW

Wind Velocity: 3-5 MPH

Color of Plume: White

Detached Plume: No

Duration of Observation: 194 Min.

SUMMARY OF AVERAGE OPACITY

	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	1143	1148	65	2.7	21	1421	1426	5	0.2
2	1149	1154	70	2.9	22	1427	1432	5	0.2
3	1155	1200	75	3.1	23	1433	1438	15	0.6
4	1201	1206	55	2.3	24	1439	1444	20	0.8
5	1207	1212	60	2.5	25	1445	1450	10	0.4
6	1213	1218	90	3.8	26	1451	1456	15	0.6
7	1219	1224	65	2.7	27	1457	1502	5	0.2
8	1225	1230	85	3.5	28	1503	1508	10	0.4
9	1231	1236	60	2.5	29	1509	1514	0	0.0
10	1237	1242	45	1.9	30	1515	1520	0	0.0
11	1246	1251	30	1.3	31				
12	1252	1257	55	2.3	32				
13	1258	1303	20	0.8	33				
14	1307	1312	20	0.8	34				
15	1345	1350	45	1.9	35				
16	1351	1356	10	0.4	36				
17	1357	1402	10	0.4	37				
18	1403	1408	15	0.6	38				
19	1409	1414	35	1.5	39				
20	1415	1420	20	0.8	40				

TABLE C-36

FACILITY D

Summary of Visible Emissions

Observer # 2

Date: 8/7/74

Type of Plant: Lime Kiln

Type of Discharge: Stack

Location of Discharge: ESP # 1

Height of Point of Discharge: 100 Ft.

Description of Background: Sky

Description of Sky: Hazy

Wind Direction: S

Color of Plume: White

Duration of Observation: 193 Min.

Distance from Observer to Discharge Point: 100 Ft.

Height of Observation Point: 75 Ft.

Direction of Observer from Discharge Point: E at start, moved to W at 13:20

Wind Velocity: 8-10 MPH

Detached Plume: No

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1	1143	1148	15	0.6
2	1149	1154	0	0.0
3	1155	1200	0	0.0
4	1201	1206	10	0.4
5	1207	1212	15	0.6
6	1213	1218	80	3.3
7	1219	1224	65	2.7
8	1225	1230	5	0.2
9	1231	1236	0	0.0
10	1237	1242	20	0.8
11	1243	1248	0	0.0
12	1249	1254	0	0.0
13	1255	1300	35	1.5
14	1301	1306	55	2.3
15	1307	1312	65	2.7
16	1313	1318	0	0.0
17	1345	1350	5	0.2
18	1351	1356	5	0.2
19	1357	1402	30	1.3
20	1403	1408	10	0.4

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
21	1409	1414	30	1.3
22	1415	1420	15	0.6
23	1421	1426	0	0.0
24	1427	1432	0	0.0
25	1433	1438	0	0.0
26	1439	1444	0	0.0
27	1445	1450	0	0.0
28	1451	1456	0	0.0
29	1457	1502	0	0.0
30	1503	1508	0	0.0
31	1509	1514	0	0.0
32	1515	1520	0	0.0
33				
34				
35				
36				
37				
38				
39				
40				

TABLE C-37

FACILITY D

Summary of Visible Emissions

Observer # 1

Date: 8/8/74

Type of Plant: Lime Kiln

Type of Discharge: Stack

Distance from Observer to Discharge Point: 100 Ft.

Location of Discharge: ESP # 1

Height of Observation Point: 80 Ft.

Height of Point of Discharge: 100 Ft.

Direction of Observer from Discharge Point: E

Description of Background: Sky

Description of Sky: Partly Cloudy

Wind Direction: S-SW

Wind Velocity: 5-10 MPH

Color of Plume: White

Detached Plume: No

Duration of Observation: 196 Min.

SUMMARY OF AVERAGE OPACITY					SUMMARY OF AVERAGE OPACITY				
	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	1026	1031	5	0.2	21	1244	1249	30	1.3
2	1032	1037	20	0.8	22	1250	1255	0	0.0
3	1038	1043	20	0.8	23	1256	1301	0	0.0
4	1044	1049	20	0.8	24	1302	1307	0	0.0
5	1050	1055	35	1.5	25	1308	1313	5	0.2
6	1056	1101	5	0.2	26	1314	1319	5	0.2
7	1102	1107	5	0.2	27	1320	1325	0	0.0
8	1108	1113	25	1.0	28	1326	1331	5	0.2
9	1114	1119	15	0.6	29	1332	1337	0	0.0
10	1120	1125	25	1.0	30	1338	1343	0	0.0
11	1126	1131	10	0.4	31	1344	1349	20	0.8
12	1132	1137	5	0.2	32	1350	1355	65	2.7
13	1138	1143	0	0.0	33				
14	1144	1149	10	0.4	34				
15	1150	1155	0	0.0	35				
16	1156	1201	5	0.2	36				
17	1220	1225	5	0.2	37				
18	1226	1231	0	0.0	38				
19	1232	1237	5	0.2	39				
20	1238	1243	0	0.0	40				

TABLE C-38

FACILITY D

Summary of Visible Emissions

Observer # 2

Date: 8/8/74

Type of Plant: Lime Kiln

Type of Discharge: Stack

Distance from Observer to Discharge Point: 100 Ft.

Location of Discharge: ESP # 1

Height of Observation Point: 80 Ft.

Height of Point of Discharge: 100 Ft.

Direction of Observer from Discharge Point: E

Description of Background: Sky

Description of Sky: Partly Cloudy

Wind Direction: S

Wind Velocity: 12-15 MPH

Color of Plume: White

Detached Plume: No

Duration of Observation: 193 Min.

SUMMARY OF AVERAGE OPACITY

	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	1026	1031	35	1.5	21	1244	1249	0	0.0
2	1032	1037	5	0.2	22	1250	1255	0	0.0
3	1038	1043	10	0.4	23	1256	1301	0	0.0
4	1044	1049	85	3.5	24	1302	1307	0	0.0
5	1050	1055	5	0.2	25	1308	1313	0	0.0
6	1056	1101	0	0.0	26	1314	1319	0	0.0
7	1102	1107	0	0.0	27	1320	1325	0	0.0
8	1108	1113	0	0.0	28	1326	1331	0	0.0
9	1114	1119	0	0.0	29	1332	1337	0	0.0
10	1120	1125	0	0.0	30	1338	1343	0	0.0
11	1126	1131	0	0.0	31	1344	1349	10	0.4
12	1132	1137	0	0.0	32	1350	1355	0	0.0
13	1138	1143	0	0.0	33				
14	1144	1149	0	0.0	34				
15	1150	1155	0	0.0	35				
16	1156	1201	0	0.0	36				
17	1220	1225	0	0.0	37				
18	1226	1231	0	0.0	38				
19	1232	1237	0	0.0	39				
20	1238	1243	0	0.0	40				

Table C-39
Summary of Test Results

Plant E
Fuel - 0.92% S Coal
Control Equipment - Baghouse

Run No. (stack,run)	1-1	2-2	1-2	3-1	3-2	2-3	Plant Average
Date (1975)	9-9	9-10	9-10	9-10	9-11	9-12	-
Test Time-Minutes	132	132	132	132	132	132	132
Stone Feed Rate-tons/hr	20	20	20	19	20	15	19
Stack Effluent							
Flow Rate-ACFM	14,138	16,670	16,058	17,859	17,599	13,895	48,108
Flow Rate-DSCFM	9,809	10,356	10,379	10,649	11,115	9,513	30,909
Temperature-°F	267	288	261	294	278	233	270
Water Vapor-Vol.%	4.45	11.87	11.60	14.71	11.22	9.25	10.5
CO_2-Vol.% dry	8.8	9.6	9.6	9.6	9.6	8.2	9.2
O_2-Vol.% dry	13.8	13.6	13.6	13.6	11.7	14.4	13.5
CO-Vol.% dry	0	0	0	0	0.2	0	0
N_2 & other gases-Vol.% dry	77.4	76.8	76.8	76.8	78.5	77.4	77.3
NO_x-ppm	208				166	288	216
CO-ppm	15	113			21	57	52
Particulate Emissions							
Front Half							
gr/DSCF	0.0099	0.0040	0.0061	0.0049	0.0072	0.0033	0.0059
gr/ACF	0.0068	0.0025	0.0040	0.0029	0.0045	0.0023	0.0038
lb/hr	0.829	0.351	0.546	0.449	0.682	0.271	1.564
lb/ton of feed rate	0.041	0.018	0.027	0.024	0.034	0.018	0.081
Total Catch							
gr/DSCF	0.0171	0.0074	0.0106	0.0123	0.0127	0.0073	0.0225
gr/ACF	0.0118	0.0046	0.0068	0.0073	0.0080	0.0050	0.0072
lb/hr	1.436	0.658	0.942	1.124	1.210	0.593	2.964
lb/ton	0.072	0.033	0.047	0.059	0.061	0.040	0.156

TABLE C-40

FACILITY E

Summary of Visible Emissions

Date: 9/9/75

Type of Plant: Lime and Cement

Type of Discharge: Stack

Location of Discharge: Baghouse Outlet #3, Stack #1, Run #1

Height of Point of Discharge: 80 Ft.

Description of Background: Sky (blue background)

Description of Sky: Clear to Partly Cloudy

Wind Direction: East

Color of Plume: White

Duration of Observation: 3 hrs.

Distance from Observer to Discharge Point: 150 Ft.

Height of Observation Point: Ground Level

Direction of Observer from Discharge Point: East

Wind Velocity: 2-5 miles/hr

Detached Plume: No

Observer No. 1

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1-4	1130	1153	0	0
5	1154	1159	75	3.1
6-12	1200	1241	0	0
13(4)	1242	1245	0	0
14(1)	1305	1305	0	0
15-25	1306	1408	0	0

TABLE C-41

FACILITY E

Summary of Visible Emissions

Date: 9/9/75

Type of Plant: Lime and Cement

Type of Discharge: Stack

Location of Discharge: Baghouse #3, Run #1,*

Height of Point of Discharge: 80 Ft.

Description of Background: Blue sky

Description of Sky: Clear

Wind Direction: SE

Color of Plume: White

Duration of Observation: 3 hrs.

Distance from Observer to Discharge Point: 60 Ft.

Height of Observation Point: Ground Level

Direction of Observer from Discharge Point: South

*From 1131-1257 Stack #2 was read for visible emissions, however, the particulate run on Stack #2 was voided at the halfway point in the run, so observer #2 switched to read Stack #1 from 1306-1400 hours.

Wind Velocity: 5-10 mph

Detached Plume: No

Observer #2

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1(5)	1131	1135	0	0
2-4	1136	1153	0	0
5	1154	1159	110	4.6
6-7	1200	1211	0	0
8	1212	1217	5.0	0.2
9-14	1218	1253	0	0
15(4)	1254	1259	0	0
16-26	1306	1405	0	0
27(4)	1406	1409	10	0.6

TABLE C-42

FACILITY E

Summary of Visible Emissions

Date: 9/10/75

Type of Plant: Lime and Cement

Type of Discharge: Stack

Location of Discharge: Outlet Baghouse #3, Stack #1, Run #2

Height of Point of Discharge: 80 Ft.

Description of Background: Sky, blue background

Description of Sky: Clear, blue sky

Wind Direction: East

Color of Plume: White

Duration of Observation: 3 hrs.

Distance from Observer to Discharge Point: 150 Ft.

Height of Observation Point: Ground Level

Direction of Observer from Discharge Point: East

Wind Velocity: 2-5 mph

Detached Plume: No

Observer No. 1

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1(5)	0819	0823	0	0
2-6	0824	0853	0	0
7	0854	0859	30	1.3
8-16	0900	0953	0	0
17(2)	0954	0955	0	0
18(3)	1015	1017	0	0
19-29	1018	1123	0	0

TABLE C-43

FACILITY E

Summary of Visible Emissions

Date: 9/10/75

Type of Plant: Lime and Cement

Type of Discharge: Stack

Location of Discharge: Baghouse #3 Outlet, Stack #1, Run #2

Height of Point of Discharge: 85 Ft.

Description of Background: Blue sky

Description of Sky: 80% Clear

Wind Direction: East

Color of Plume: White

Duration of Observation: 3 hrs.

Distance from Observer to Discharge Point: 60 Ft

Height of Observation Point: Ground Level

Direction of Observer from Discharge Point: Southeast

Wind Velocity: 0-10 mph

Detached Plume: No

Observer No. 2

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1(5)	0819	0823	0	0
2-6	0824	0853	0	0
7	0854	0859	40	1.7
8-13	0900	0935	0	0
14	0936	0941	10	0.4
15-25	0942	1047	0	0
26	1048	1053	10	0.4
27-31	1054	1122	0	0

TABLE C-44

FACILITY E

Summary of Visible Emissions

Date: 9/10/75

Type of Plant: Lime and Cement

Type of Discharge: Stack

Location of Discharge: Baghouse #3 Outlet, Stack #3, Run #1

Height of Point of Discharge: 80 Ft.

Description of Background: Clear to partly cloudy (blue to white) sky

Description of Sky: Clear to Partly Cloudy

Wind Direction: East

Color of Plume: White

Duration of Observation: 2 hr. 42 min.

Distance from Observer to Discharge Point: 150 Ft.

Height of Observation Point: Ground Level

Direction of Observer from Discharge Point: East

Wind Velocity: 2-5 mph

Detached Plume: No

Observer No. 1

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1-28	1300	1547	0	0

TABLE C-45

FACILITY E

Summary of Visible Emissions

Date: 9/10/75

Type of Plant: Lime and Cement

Type of Discharge: Stack

Location of Discharge: Outlet Baghouse #3, Stack #3, Run #1

Height of Point of Discharge: 80 Ft.

Description of Background: 50% Clear sky, white and blue background

Description of Sky: Partly cloudy

Wind Direction: East

Color of Plume: White

Duration of Observation: 2 hr. 41 min.

Distance from Observer to Discharge Point: 90 Ft.

Height of Observation Point: Ground Level

Direction of Observer from Discharge Point: Southeast

Wind Velocity: 0-5 mph

Detached Plume: No

Observer No. 2

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1-27	1300	1541	0	0

TABLE C-46

FACILITY E

Summary of Visible Emissions

Date: 9/11/75

Type of Plant: Lime and Cement

Type of Discharge: Stack

Location of Discharge: Outlet Baghouse #3, Stack #3, Run #2

Height of Point of Discharge: 80 Ft.

Description of Background: Blue sky background

Description of Sky: Blue, clear skys; white background 0908-0954, 1005-1006, 1018-1034

Wind Direction: East

Color of Plume: White

Duration of Observation: 2 hrs. 34 min.

Distance from Observer to Discharge Point: 150 Ft.

Height of Observation Point: Ground Level

Direction of Observer from Discharge Point: East

Wind Velocity: 2-5 mph

Detached Plume: No

Observer No. 1

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1-26	0800	1034	0	0

TABLE C-47

FACILITY E

Summary of Visible Emissions

Date: 9/11/75

Type of Plant: Lime and Cement

Type of Discharge: Stack

Location of Discharge: Outlet #3 Baghouse, Stack #3, Run #2

Height of Point of Discharge: 80 Ft.

Description of Background: Blue to White Sky

Description of Sky: 95% Clear

Wind Direction: East

Color of Plume: White

Duration of Observation: 2 hr. 33 min.

Distance from Observer to Discharge Point: 90 Ft.

Height of Observation Point: Ground Level

Direction of Observer from Discharge Point: Southeast

Wind Velocity: 0-10 mph

Detached Plume: No

Observer #2

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1(1)	0805	0805	0	0
2-4	0806	0823	0	0
5	0824	0829	35	1.5
6	0830	0835	5	1.5
7	0836	0841	30	1.3
8-23	0842	1017	0	0
24	1018	1023	10	0.4
25	1024	1029	0	0
26(4)	1030	1033	0	0

Table C-48
Summary of Test Results

Plant F
Fuel - 1.86% S Coal
Control Equipment - 15 IWC Scrubber

Run No.	1	2	3	Average
Date (1975)	9/15	9/16	9/16	
Test Time-Minutes	120	120	120	120
Stone Feed Rate-tons/hr	51.6	51.6	51.6	51.6
Stack Effluent				
Flow Rate-ACFM	139,222	137,890	133,885	136,999
Flow Rate-DSCFM	97,037	97,021	91,216	95,091
Temperature-°F	148	147	151	149
Water Vapor-Vol.%	19.81	18.73	20.96	19.80
CO_2-Vol.% dry	12.7	12.3	13.6	12.9
O_2-Vol. % dry	11.8	11.8	11.2	11.6
CO-Vol. % dry	0	0	0	0
N_2 & other gases-Vol.% dry	75.6	75.9	75.2	75.5
NO_x-ppm	121	100	89	103
CO-ppm	34.9	17.5	103.7	52
Particulate Emissions				
Front Half				
gr/DSCF	0.0296	0.0211	0.0315	0.0274
gr/ACF	0.0206	0.0148	0.0215	0.0190
lb/hr	24.626	17.510	24.628	22.255
lb/ton of feed rate	0.477	0.339	0.477	0.431
Total Catch				
gr/DSCF	0.0360	0.0259	0.0375	0.0331
gr/ACF	0.0251	0.0182	0.0256	0.0230
lb/hr	29.952	21.497	29.292	26.914
lb/ton of feed rate	0.580	0.417	0.568	0.522

TABLE C-49

FACILITY F

Summary of Visible Emissions

Date: 9-16-75

Type of Plant: Lime

Type of Discharge: #3 Kiln Venturi Scrubber Stack

Height of Point of Discharge: 85 Ft.

Distance from Observer to Discharge Point: 300 Ft.

Height of Observation Point: Ground Level

Direction of Observer from Discharge Point: ESE

Description of Background: Sky

Description of Sky: Partly Cloudy

Wind Direction: NE

Wind Velocity: 5 MPH

Color of Plume: White (Steam)

Detached Plume: No

Duration of Observation: 1 hr.

SUMMARY OF AVERAGE OPACITY

			Observer No. 2		Observer No. 3	
	Time		Opacity		Opacity	
Set Number	Start	End	Sum	Average	Sum	Average
1	1500	1505*	10	0.4	10	0.4
2	1506	1511*	0	0	0	0
3 -10	1512	1559	0	0	0	0

*Observer No. 1

Table C-50
Summary of Test Results

Plant G
Fuel: Lime-3.53% S Coal, DBD-2.96% S Coal
Control Equipment: 15 IWC Scrubber

Kiln	Lime	Lime	DBD	DBD
Test Location	Inlet	Outlet	Inlet	Outlet
Date (1975)	12/8	12/3-6	12/9	12/9
Number of Tests	6	6	6	6
Stone Feed Rate-TPH	33.7	31.2	23.4	23.4
Stack Effluent				
Flow Rate-ACFM	92,510	91,970	82,200	82,200
Flow Rate-DSCFM	59,180	57,674	50,450	50,450
Temperature-°F	980	153	1500	160
Water Vapor-Vol.%	5.65	22.7	8.4	26.7
CO_2-Vol.% dry	19.7	17.0	18.8	17.4
O_2-Vol.% dry	10.0	11.8	9.5	10.7
CO-Vol.% dry	0	0	0	0
N_2 & other gases-Vol.% dry	70.3	71.2	71.7	71.9
SO_2- EPA Method 6				
lb/hr	272	2.9	179	7.8
ppm	450	5.0	347	15
Dynascience				
ppm	435	-	310	37
CO-ppm	110	321	72	92

Table C-51
Summary of Test Results
Plant H
Fuel: 2.97% S Coal
Control Equipment: Baghouse

Run No.	4	5	8	9	10	11	Average
Date (1976)	1/29	1/29	1/31	1/31	1/31	1/31	
Number of Tests	5	6	6	6	6	5	
Stone Feed Rate-TPH	170	170	170	172	172	172	171
Stack Effluent							
Flow Rate-ACFM	240,022	248,451	249,045	262,698	240,616	288,148	248,451
Flow Rate-DSCFM	161,740	167,420	167,820	177,020	162,140	194,170	167,420
Temperature-°F	290	290	290	290	290	290	290
Water Vapor-Vol.%	4.88	4.88	4.87	4.89	4.89	4.85	4.88
CO_2-Vol.% dry	-	12.0	16.8	-	17.1	15.3	15.3
O_2-Vol.% dry	-	13.8	11.2	-	10.8	12.3	12.0
CO-Vol.% dry	-	0	0	-	0	0	0
N_2& other gases-Vol.% dry	-	74.2	72.0	-	72.1	72.4	72.7
SO_2-ppm	256	121	284	194	143	196	199

Table C-52

Atmospheric Hydrator
Summary of Particulate Test Results

Plant	H-A	H-B	B*
Control Equipment	Wet Scrubber	Wet Scrubber	Wet Scrubber
Lime Feed Rate-tons/hr	14	17-18	14
Water Feed Rate-gals/min	28	34	45
Hydrated Lime Production tons/hr	17-18	22	17
Stack Effluent			
Flow Rate-ACFM	10,980	7,646	10,320
Flow Rate-DSCFM	4,824	1,338	4,560
Temperature-°F	176	201	175
Water Vapor-Vol. %	46.7	77.9	47
CO_2-Vol. % dry	0	0	0
O_2-Vol. % dry	20.42	21.0	21.0
CO-Vol. % dry	0	0	0
N_2 and other gases-Vol. % dry	79.57	79.0	79.0
Particulate Emissions			
Probe & Filter Catch			
gr/DSCF	0.0286	0.1856	0.024
gr/ACF	0.0125	0.0325	0.011
lb/hr	1.17	2.084	0.950
lb/ton feed	0.084	0.117	0.068
kg/Mg ton feed	0.042	0.059	0.034

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*Plant test results using EPA Method 5.

Table C-53

Summary of Test Results

Plant H-A
Atmospheric Hydrator
Control Equipment - Ducon Scrubber

Run No.	1	2	3	Average
Date	4/16/74	4/17/74	4/18/74	--
Test Time-Minutes	240	240	125	
Lime Feed Rate-tons/hr	14	14	14	14
Water Feed Rate-tons/hr	7	7	7	7
Hydrated Lime Production tons/hr	17-18	17-18	17-18	17-18
Stack Effluent				
Flow Rate-ACFM	10,701	11,154	11,084	10,980
Flow Rate-DSCFM	4,901	4,775	4,797	4,824
Temperature-°F	174	178	177	176
Water Vapor-Vol.%	44.5	48.0	47.5	46.7
CO_2-Vol.% dry	0	0	0	0
O_2-Vol.% dry	20.43	20.43	20.43	20.43
CO-Vol.% dry	0	0	0	0
N_2 and other gases-Vol.% dry	79.57	79.57	79.57	79.57
Particulate Emissions				
Probe & Filter Catch				
gr/DSCF	0.0216	0.0269	0.0366	0.0286
gr/ACF	0.0099	0.0115	0.0158	0.0125
lb/hr	0.91	1.10	1.50	1.17
lb/ton	0.065	0.079	0.107	0.084
Total Catch				
gr/DSCF	0.0269	0.0346	0.0403	0.0342
gr/ACF	0.0123	0.0148	0.0175	0.0149
lb/hr	1.13	1.42	1.66	1.40
lb/ton	0.081	0.101	0.119	0.100

TABLE C-54
FACILITY H-A
Summary of Visible Emissions

Date: 4/18/74

Type of Plant: Lime Hydration

Type of Discharge: Stack

Distance from Observer to Discharge Point: ~ 200'

Location of Discharge: Hydrator Exhaust

Height of Observation Point: Ground Level

Height of Point of Discharge: ~ 100'

Direction of Observer from Discharge Point: E

Description of Background: Sky

Description of Sky: Overcast

Wind Direction: S

Wind Velocity: 0-10

Color of Plume: Steam Plume

Detached Plume: No

Duration of Observation: 1 hour

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1	10:13	10:19	0	0
2	10:19	10:25	0	0
3	10:25	10:31	0	0
4	10:31	10:37	0	0
5	10:37	10:43	0	0
6	10:43	10:49	0	0
7	10:49	10:55	0	0
8	10:55	11:01	0	0
9	11:01	11:07	0	0
10	11:07	11:13	0	0
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				

Table C-55
Summary of Test Results
Plant H-B
Atmospheric Hydrator
Control Equipment - Ducon Scrubber

Run No.	1	2	3	Average
Date (1975)	9-12	9-17	9-17	-
Test Time-Minutes	128	128	128	128
Lime Feed Rate-tons/hr	18	17.2	18	17.7
Hydrated Lime Production-tons/hr	22	21	22	21.7
Water to Hydrator-gpm	13.3	15.3	16.5	15
Water to Scrubber-gpm	20	19	19	19
Stack Effluent				
Flow Rate-ACFM	7291	8191	7455	7649
Flow Rate-DSCFM	1207	1576	1232	1338
Temperature-°F	201	200	203	201
Water Vapor-Vol %	79.1	75.7	79.0	77.9
CO_2-Vol.% dry	0	0	0	0
O_2-Vol.% dry	21.0	21.0	21.0	21.0
CO-Vol.% dry	0	0	0	0
N_2 & other gases-Vol.% dry	79.0	79.0	79.0	79.0
Particulate Emissions				
Probe & Filter Catch				
gr/DSCF	0.1139	0.1439	0.2962	0.1856
gr/ACF	0.0169	0.0299	0.0489	0.0325
lb/hr	1.179	1.944	3.128	2.084
lb/ton	0.0655	0.113	0.173	0.117
Total Catch				
gr/DSCF	0.1320	0.1487	0.3097	0.1968
gr/ACF	0.0219	0.0286	0.0512	0.0344
lb/hr	1.365	2.008	3.271	2.215
lb/ton	0.0758	0.117	0.182	0.125

Plant A

The facility tested was a rotary lime kiln which produces a high calcium metallurgical lime. Emissions are controlled by a baghouse which receives the kiln off-gas after it is cooled by a combination of water spray and tempering air. Each of the six stacks from the baghouse was tested once using EPA Method 5.

The kiln production was steady at 460 tons/day during the test period, which is 92 percent of the rated production capacity of 500 tons/day. Because of the low particulate concentrations, the testing was performed during four hour periods. A summary of the complete testing results is shown in Table C-56. Visible emissions were negligible throughout the test periods. (See Table C-57 through C-63.)

The plant A baghouse is not typical of those in use in the lime industry. Large quantities of dilution air infiltrate through the corrugated asbestos siding and doors into the clean air side of the baghouse. It is unknown how this affects the performance of the baghouse, but this baghouse did not perform as well as the two other baghouses (plants B and E) that were source tested in conjunction with this study.

Plant A Baghouse -

Type - Pressure Baghouse

Bag Material - Fiberglass fabric

No. of Compartments - 12 compartment with 78 bags in each compartment

No. of Stacks - 6

Design Pressure Drop - 2 1/3 to 3 I.W.C

Cloth Area - 87,048 ft^2

Bag Cleaning - Reverse air flow (one compartment at a time)

Cloth Area (operating) - 79,794 ft^2

Fan Design - 140,000 ACFM @600°F

Design Air to Cloth Ratio - 1.75:1

Table C-56
Summary of Test Results

Plant A
Fuel-1.28% S Coal
Control Equipment - Baghouse

Run No.[1]	1	2	3	4	5	6	
Date	6/11/74	6/11/74	6/12/74	6/12/74	6/13/74	6/13/74	---
Test Time-Minutes	240	240	240	240	240	240	240
Stone Feed Rate-tons/hr	37.7	37.7	38.6	38.6	38.2	38.2	38.2
Stack Effluent							
Flow Rate-ACFM	37,049	33,032	35,532	32,375	38,024	35,078	
Flow Rate-DSCFM	23,797	22,407	23,162	21,247	24,878	23,156	
Temperature-°F	290	263	284	269	272	273	275
Water Vapor-Vol.%	6.5	4.8	6.3	7.5	7.4	6.5	6.5
CO_2-Vol.% dry	6.8	6.8	7.0	7.0	7.0	7.0	6.9
O_2-Vol.% dry	19.5	19.5	16.5	16.5	16.5	16.5	17.5
CO-Vol.% dry	0	0	0	0	0	0	0
N_2 and other gases-Vol.% dry	73.7	73.7	76.5	76.5	76.5	76.5	75.6
NO_x-ppm	41.8		38.1		72.9		50.9
SO_2-ppm	80.9	77.4	106.0	90.7	100.0	94.8	91.7
CO-ppm	15		580		30		208
Particulate Emissions							
Probe & Filter Catch							
gr/DSCF	0.0223	0.0216	0.0098	0.0109	0.0125	0.0116	0.0148
gr/ACF	0.0143	0.0146	0.0064	0.0072	0.0082	0.0076	0.0097
lb/hr	4.55	4.06	1.96	1.98	2.67	2.30	
lb/ton	0.121	0.108	0.058	0.051	0.070	0.060	
Total Catch							
gr/DSCF	0.0361	0.0404	0.0320	0.0254	0.0257	0.0319	0.0319
gr/ACF	0.0232	0.0274	0.0208	0.0167	0.0168	0.0211	0.0209
lb/hr	7.36	7.76	6.36	4.62	5.47	6.33	
lb/ton	0.195	0.206	0.165	0.120	0.143	0.166	

(1) One test on each of 6 stacks.

TABLE C-57

FACILITY A

Summary of Visible Emissions

Observer # 1

Date: 6/11/74

Type of Plant: Lime

Type of Discharge: Stack #1 & #2

Location of Discharge: #5 Kiln

Height of Point of Discharge: ~ 80'

Description of Background: Sky

Description of Sky: Overcast

Wind Direction: SE

Color of Plume: White

Duration of Observation: 4 hours

Distance from Observer to Discharge Point: ~ 100

Height of Observation Point: Ground Level

Direction of Observer from Discharge Point:

Wind Velocity: ~ 20

Detached Plume: No

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1	12:38	12:44	10	0.4
2	12:44	12:50	0	0
3	12:50	12:56	0	0
4	12:56	13:02	0	0
5	13:02	13:08	0	0
6	13:08	13:14	0	0
7	13:14	13:20	25	1.0
8	13:20	13:26	0	0
9	13:26	13:32	0	0
10	13:32	13:38	0	0
11	13:38	13:44	0	0
12	13:44	13:50	0	0
13	13:50	13:56	15	0.6
14	13:56	14:02	0	0
15	14:02	14:08	0	0
16	14:08	14:14	0	0
17	14:14	14:20	0	0
18	14:20	14:26	0	0
19	14:26	14:32	0	0
20	14:32	14:38	0	0

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
21	15:56	16:02	0	0
22	16:02	16:08	0	0
23	16:08	16:14	0	0
24	16:14	16:20	0	0
25	16:20	16:26	0	0
26	16:26	16:32	0	0
27	16:32	16:38	0	0
28	16:38	16:44	10	0.4
29	16:44	16:50	0	0
30	16:50	16:56	0	0
31	16:56	17:02	0	0
32	17:02	17:08	0	0
33	17:08	17:14	0	0
34	17:14	17:20	0	0
35	17:20	17:26	0	0
36	17:26	17:32	0	0
37	17:32	17:38	0	0
38	17:38	17:44	0	0
39	17:44	17:50	0	0
40	17:50	17:56	0	0

TABLE C-58

FACILITY A

Summary of Visible Emissions

Observer # 2

Date: 6/11/74

Type of Plant: Lime

Type of Discharge: Stack #1 & #2 Distance from Observer to Discharge Point: ~ 100'

Location of Discharge: #5 Kiln Height of Observation Point: Ground Level

Height of Point of Discharge: ~ 80' Direction of Observer from Discharge Point:

Description of Background: Sky

Description of Sky: Partly Cloudy

Wind Direction: SE Wind Velocity: 5-10

Color of Plume: White Detached Plume: No

Duration of Observation: 2 hours

SUMMARY OF AVERAGE OPACITY					SUMMARY OF AVERAGE OPACITY				
	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	16:01	16:07	0	0	21				
2	16:07	16:13	0	0	22				
3	16:13	16:19	0	0	23				
4	16:19	16:25	0	0	24				
5	16:25	16:31	0	0	25				
6	16:31	16:37	0	0	26				
7	16:37	16:43	0	0	27				
8	16:43	16:49	0	0	28				
9	16:49	16:55	0	0	29				
10	16:55	17:01	0	0	30				
11	17:01	17:07	0	0	31				
12	17:07	17:13	0	0	32				
13	17:13	17:19	0	0	33				
14	17:19	17:25	0	0	34				
15	17:25	17:31	0	0	35				
16	17:31	17:37	0	0	36				
17	17:37	17:43	0	0	37				
18	17:43	17:49	0	0	38				
19	17:49	17:55	0	0	39				
20	17:55	18:01	0	0	40				

TABLE C-59

FACILITY A

Summary of Visible Emissions

Observer # 1

Date: 6/12/74

Type of Plant: Lime

Type of Discharge: Stack #3 & #4

Location of Discharge: #5 Kiln

Height of Point of Discharge: ~ 80'

Description of Background: Sky

Description of Sky: Clear to Partly Cloudy

Wind Direction: SW

Color of Plume: White

Duration of Observation: ~ 4 hours

Distance from Observer to Discharge Point: AM ~ 25' PM ~ 100'

Height of Observation Point: AM ~ 70' PM-Ground Leve

Direction of Observer from Discharge Point:

Wind Velocity: ~ 20

Detached Plume: No

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1	10:53	10:59	0	0
2	10:59	11:05	30	1.3
3	11:05	11:11	5	0.2
4	11:11	11:17	0	0
5	11:17	11:23	5	0.2
6	11:23	11:29	0	0
7	11:29	11:35	0	0
8	11:35	11:41	0	0
9	11:41	11:47	0	0
10	11:47	11:53	0	0
11	11:53	11:59	0	0
12	11:59	12:05	0	0
13	12:05	12:11	25	1.0
14	12:11	12:17	0	0
15	12:17	12:23	0	0
16	12:23	12:29	0	0
17	12:29	12:35	0	0
18	12:35	12:41	0	0
19	12:41	12:47	0	0
20	13:42	13:48	0	0

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
21	13:48	13:54	0	0
22	13:54	14:00	0	0
23	14:00	14:06	0	0
24	14:06	14:12	0	0
25	14:12	14:18	0	0
26	14:18	14:24	0	0
27	14:24	14:30	0	0
28	14:30	14:36	0	0
29	14:36	14:42	0	0
30	14:42	14:48	0	0
31	14:48	14:54	0	0
32	14:54	15:00	0	0
33	15:00	15:06	0	0
34	15:06	15:12	0	0
35	15:12	15:18	0	0
36	15:18	15:24	0	0
37	15:24	15:30	0	0
38	15:30	15:36	0	0
39	15:42	15:48	0	0
40				

TABLE C-60

FACILITY A

Summary of Visible Emissions
Observer # 2

Date: 6/12/74

Type of Plant: Lime

Type of Discharge: Stack #3 & #4

Location of Discharge: #5 Kiln

Height of Point of Discharge: ~ 80'

Description of Background: Sky

Description of Sky: Clear to Partly Cloudy

Wind Direction: SW

Color of Plume: White

Duration of Observation: 4 hours

Distance from Observer to Discharge Point:
AM ~ 25' PM ~ 100'

Height of Observation Point:
AM ~ 70' PM-Ground Level

Direction of Observer from Discharge Point:

Wind Velocity: ~ 20

Detached Plume: No

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1	10:53	10:59	0	0
2	10:59	11:05	20	0.8
3	11:05	11:11	0	0
4	11:11	11:17	0	0
5	11:17	11:23	0	0
6	11:23	11:29	0	0
7	11:29	11:35	0	0
8	11:35	11:41	0	0
9	11:41	11:47	0	0
10	11:47	11:53	0	0
11	11:53	11:59	0	0
12	11:59	12:05	0	0
13	12:05	12:11	10	0.4
14	12:11	12:17	0	0
15	12:17	12:23	0	0
16	12:23	12:29	0	0
17	12:29	12:35	0	0
18	12:35	12:41	0	0
19	12:41	12:47	0	0
20	12:47	12:53	10	0.4

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
21	13:05	13:11	0	0
22	13:11	13:17	0	0
23	13:17	13:23	0	0
24	13:23	13:29	0	0
25	13:29	13:35	0	0
26	13:35	13:41	0	0
27	13:41	13:47	0	0
28	13:47	13:53	0	0
29	13:53	13:59	0	0
30	13:59	14:05	0	0
31	14:05	14:11	0	0
32	14:11	14:17	0	0
33	14:17	14:23	0	0
34	14:23	14:29	0	0
35	14:29	14:35	0	0
36	14:35	14:41	0	0
37	14:41	14:47	0	0
38	14:47	14:53	0	0
39	14:53	14:59	0	0
40	14:59	15:05	0	0

TABLE C-61

FACILITY A

Summary of Visible Emissions
Observer # 1

Date: 6/13/74

Type of Plant: Lime

Type of Discharge: Stack #5

Distance from Observer to Discharge Point: ~25'

Location of Discharge: #5 Kiln

Height of Observation Point: ~ 70'

Height of Point of Discharge: ~ 80'

Direction of Observer from Discharge Point:

Description of Background: Sky

Description of Sky: Partly Cloudy

Wind Direction: S

Wind Velocity: ~ 20

Color of Plume: White

Detached Plume: No

Duration of Observation: 2 Hours

SUMMARY OF AVERAGE OPACITY | SUMMARY OF AVERAGE OPACITY

	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	9:31	9:37	0	0	21				
2	9:37	9:43	30	1.3	22				
3	9:43	9:49	0	0	23				
4	9:49	9:55	0	0	24				
5	9:55	10:01	0	0	25				
6	10:01	10:07	0	0	26				
7	10:07	10:13	0	0	27				
8	10:13	10:19	0	0	28				
9	10:19	10:25	0	0	29				
10	10:25	10:31	0	0	30				
11	10:31	10:37	0	0	31				
12	10:37	10:43	0	0	32				
13	10:43	10:49	0	0	33				
14	10:49	10:55	0	0	34				
15	10:55	11:01	0	0	35				
16	11:01	11:07	0	0	36				
17	11:07	11:13	0	0	37				
18	11:13	11:19	0	0	38				
19	11:19	11:25	0	0	39				
20	11:25	11:31	0	0	40				

TABLE C-62

FACILITY A

Summary of Visible Emissions

Observer #1

Date: 6/13/74

Type of Plant: Lime

Type of Discharge: Stack #6

Distance from Observer to Discharge Point: ~ 100'

Location of Discharge: #5 kiln

Height of Observation Point: Ground Level

Height of Point of Discharge: ~ 80'

Direction of Observer from Discharge Point:

Description of Background: Sky

Description of Sky: Overcast

Wind Direction: S SW

Wind Velocity: 5-10

Color of Plume: White

Detached Plume: NO

Duration of Observation: 2 hours

SUMMARY OF AVERAGE OPACITY					SUMMARY OF AVERAGE OPACITY				
	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	11:46	11:52	0	0	21				
2	11:52	11:58	5	0.2	22				
3	11:58	12:04	0	0	23				
4	12:04	12:10	0	0	24				
5	12:10	12:16	0	0	25				
6	12:16	12:22	0	0	26				
7	12:22	12:28	0	0	27				
8	12:28	12:34	0	0	28				
9	12:34	12:40	0	0	29				
10	12:40	12:46	0	0	30				
11	12:46	12:52	0	0	31				
12	12:52	12:58	0	0	32				
13	12:58	13:04	0	0	33				
14	13:04	13:10	0	0	34				
15	13:10	13:16	0	0	35				
16	13:16	13:22	0	0	36				
17	13:22	13:28	0	0	37				
18	13:28	13:34	0	0	38				
19	13:34	13:40	0	0	39				
20	13:40	13:46	0	0	40				

TABLE C-63

FACILITY A

Summary of Visible Emissions
Observer #2

Date: 6/13/74

Type of Plant: Lime

Type of Discharge: Stack #6

Distance from Observer to Discharge Point: ~ 100'

Location of Discharge: #5 Kiln

Height of Observation Point: Ground Level

Height of Point of Discharge: ~ 80'

Direction of Observer from Discharge Point:

Description of Background: Sky

Description of Sky: Overcast

Wind Direction: S SW

Wind Velocity: 5-10

Color of Plume: White

Detached Plume: No

Duration of Observation: 1 hour 46 min.

SUMMARY OF AVERAGE OPACITY | SUMMARY OF AVERAGE OPACITY

	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	12:10	12:16	0	0	21				
2	12:16	12:22	0	0	22				
3	12:22	12:28	0	0	23				
4	12:28	12:34	0	0	24				
5	12:34	12:40	0	0	25				
6	12:40	12:46	0	0	26				
7	12:46	12:52	0	0	27				
8	12:52	12:58	0	0	28				
9	12:58	13:04	0	0	29				
10	13:04	13:10	0	0	30				
11	13:10	13:16	0	0	31				
12	13:16	13:22	0	0	32				
13	13:22	13:28	0	0	33				
14	13:28	13:34	0	0	34				
15	13:34	13:40	0	0	35				
16	13:40	13:46	0	0	36				
17	13:46	13:52	0	0	37				
18	13:52	13:56	0	0	38				
19					39				
20					40				

APPENDIX D

EMISSION MEASUREMENT AND CONTINUOUS MONITORING

D. 1 Emission Measurement Methods

For the lime industry investigation, the Environmental Protection Agency used Method 5 for particulate emission measurement, Method 6 for sulfur dioxide emission measurement, and Method 9 for visible emissions measurement. These have been established as reference methods in Federal Register, v36 n247 December 23, 1971, and Federal Register, v39 n219 November 12, 1974, respectively.

Method 5, as prescribed in the above reference, was conducted without difficulty at all of the rotary kiln exhausts tested. Difficulties were encountered when Method 5 was used at lime hydrator exhausts. It was found that isokinetic sampling conditions could not be maintained by using the average prevailing exhaust gas parameters for the sampling nomograph described in APTD-0576. This is due to the high water vapor content at saturation for the exhaust gas temperatures and the large moisture content variations caused by relatively small temperature changes. At Facility H-A, this difficulty was countered by continually resetting the sampling nomograph by assuming saturated conditions at the measured exhaust temperature. At the moisture content levels present at this facility (44-48 percent), this procedure was found adequate. Two of the three test runs met the allowable isokinetic condition range of 90-110 percent, with the third being only slightly high at 115 percent. At Facility H-B, the exhaust gas temperatures were such that the moisture content ranged from 76-79 percent by volume. It was necessary to extend the moisture content scale of the nomograph for use at these water vapor content levels. The procedure for accomplishing this extension has been described in "Adjustments in the EPA Nomograph for Different Pitot Tube Coefficients and Dry Molecular Weights" (Stack Sampling News, 2:4-11 October 1974) by R. T. Shigehara. With this extended nomograph, sampling was conducted in a like manner to that used at Plant H-A. Of three tests performed, one met the allowable isokinetic condition range at 99 percent, one was low at 89 percent, and one was high at 118 percent.

Testing was also performed at a third hydrator facility using the extended nomograph where the exhaust gas moisture content ranged from 76-86 percent. The resulting isokinetic conditions ranged from 140 to 190 percent and were regarded as unacceptable.

The variability of isokinetic conditions obtained at the last two facilities is probably due to the fact that a ± 3 volume percent error in average moisture estimation at the 75 to 85% level will result in isokinetic deviations greater than the allowable ± 10%. This difficulty was compounded at the last testing described by the variability of the exhaust gas moisture content.

An alternate procedure that can be used when continuous temperature monitoring and nomograph adjustment are not adequate to maintain isokinetic conditions is the measurement of sampling rate prior to water vapor condensation in the sampling train. An example of how this can be accomplished is the use of a calibrated orifice installed on the sampling probe immediately following the nozzle. In this configuration, the sampling rate necessary for isokinetic conditions can be directly related to the exhaust gas velocity without a correction for moisture content.

For the majority of the rotary kilns tested, visible emissions determinations could be made with little or no difficulty, depending on the prevailing weather conditions. An exception was encountered at a facility that employed a water scrubber for emissions control. The highly visible, attached water vapor plume and overcast weather rendered detection of other possible visible emissions virtually impossible.

At both hydrator facilities tested, water vapor plumes from the scrubber control devices rendered visible emissions determination either extremely difficult or impossible.

Method 6 for sulfur dioxide measurement was used with varying degrees of success at sampling locations prior to and/or after emission control devices at the various facilities tested in the investigation. At Facilities A, B, and C, Method 6, as prescribed in the above reference, was used after control devices. At Facility D, Method 6 procedures with larger impingers and proportionally larger amounts of absorbing solutions were used after a control device to facilitate longer sampling durations. At Facilities E, F, G, and H, Method 6 was used both before and after control devices. In addition, instrumental SO_2 analyzers were operated to obtain independent comparative measurements.

No testing problems were reported at Facilities A, B, C, or D and the results are not unreasonable for the type fuels used at the facilities. Difficulties were encountered at Facilities E, F, G, and H. At Facility E, five of the six tests at the baghouse inlet resulted in SO_2 concentrations comparable to those obtained with an instrument during a non-simultaneous period. The sixth result was a zero SO_2 concentration. At the baghouse outlet, five of the six runs resulted in zero concentration, with the sixth result comparable to non-simultaneous instrumental results.

At Facility F three tests were performed at the inlet and outlet of the scrubber. Two of the tests at the inlet resulted in zero concentration while the third yielded a result that was approximately one-half that yielded by a simultaneously operated instrument.

At the scrubber outlet, all measurements by Method 6 and the instrument resulted in zero SO_2 concentrations. Since the emission control device was a scrubber, it is reasonable to conclude that the SO_2 concentrations in this case were less than the minimum detectible levels for both Method 6 and the instrument, which is about 10 ppmv.

At Facility G, six tests were performed before and after the scrubbers on each of two kilns. At the outlet locations, Method 6 was used with no particulate filtration (glass wool) in the sampling probes. The results compared favorably with instrumental measurements in that no response was obtained for Method 6 results that were at approximately the instrument's minimum detection limit. Initial testing at the soft-burned lime scrubber inlet were unsuccessful. When particulate filtration at the gas stream temperature was used, or when visible accumulations of particulates were observed in the probe-to-sampling-train glassware, either zero or low (compared to instrumental measurements) SO_2 concentrations were obtained. After the sampling interface system was modified to incorporate a probe with shielded gas pickup ports for particulate deflection, all Method 6 measurements were comparable to instrument results.

At Facility H, tests were performed on each of three inlets to the baghouse and at the baghouse outlet. At the inlet locations, shielded gas probes were used for both Method 6 and instrumental sampling. It was found that this was not adequate to prevent particulate accumulation in the Method 6 connection glassware or the instrument sampling lines. No successful interface system could be developed at the test site. Therefore, all measurements except those made during the first test run are questionable. At the baghouse outlet, no particulate filtration was used and the Method 6 data compare favorably with instrument results. No particulate accumulations were observed during outlet sampling.

Because of the questionable SO_2 results obtained at the above facilities, the gas stream parameters and sampling procedures at Facilities E, F, G, and H were reviewed in attempt to identify a condition that would consistently yield low SO_2 results. It was found that zero SO_2 concentration results were obtained under a variety of temperatures, gas compositions, and particulate loadings. The only consistent variable was that particulates were accumulated by either in-stack filtration or deposition in the Method 6 glassware.

From thermodynamic and kinetic considerations of the potential particulate-SO_2 reactions under dry conditions,$^{(1,2,3)}$ the following qualitative statements can be made:

1. The equilibrium conversion of gaseous SO_2 to solid sulfur compounds will be increased by a) increased temperature and b) the increased ratios of gas/solid reactants versus products.
2. The rate of conversion will be increased by a) increased solid surface area for reaction (greater ratio of small particles), and b) increased contact residence time.

No quantitative estimates of reaction can be made from theoretical considerations because of the complexity and variability of the systems.

For reaction systems where water is present, the mechanisms could be different depending on the amount present and physical state of the water. The most reactive conditions would be expected when water is present in the liquid state.

Laboratory tests have shown that dry, CaO-SO_2 reactions at temperatures up to 280°F do not occur to a detectible extent at the sampling rate range used with Method 6 procedures. These data cannot be used to estimate the degree of reactions at higher temperatures.

An additional series of tests are being conducted in order to identify any possible conditions under which reaction will interfere in a wet CaO-SO_2.

An additional series of tests with known quantities of SO_2, CaO, and stack moisture content have demonstrated that, under high moisture conditions, significant gains in particulate weight can be experienced on the filer of the Method 5 train. At temperatures up to 300°F, SO_2 concentrations of about 600 ppm, and moisture content greater than 22 percent by volume, the particulate weight gain ranged from 6 to 15 percent of a 100 to 120 mg total catch. As the CaO used for these tests was obtained from products samples, there remains some question about how much of this apparent CaO-SO_2 reaction would occur in the stack prior to sampling.

Combining the theoretical considerations and experimental results with general conditions present at Facilities E, F, G, and H result in two possible causes for particulate interference with sulfur dioxide determination. These are (1) dry CaO-SO_2 reaction and subsequent filtration at temperatures greater than 280°F and (2) high gas moisture reaction with CaO and SO_2. While no absolute statement is possible, in the cases where zero or low results were obtained either one or both of the above causes were potentially present.

In order to avoid potential interference problems, particulate entrainment should be prevented or minimized to the extent that no solid accumulations are visible in the sample interface system. No in-stack filtration should be used at gas temperatures greater than 280°F. If necessary, all connecting apparatus prior to the absorbing solutions should be heated to prevent moisture condensation.

D.2 Monitoring Systems

The visible emissions monitoring systems that are adequate for other stationary sources, such as steam generators, covered by performance specifications contained in Appendix B of 40 CFR 60 (Federal Register, October 6, 1975), should also be applicable to lime plants, except where condensed moisture is present in the exhaust stream. When scrubbers are used for emission reduction from rotary lime kilns and hydrators, monitoring of visible emissions is not required.

Equipment and installation costs for visible emissions monitoring are estimated to be about $18,000 to $20,000 per site. Annual operating costs, which includes the recording and reducing of data, are estimated at about $8,000 to $9,000 per site. Some economics in operating costs may be achieved if multiple systems are required at a given facility.

D.3 Performance Test Methods

The recommended performance test method for particulate matter is Method 5 (Appendix A, 40 CFR 60, Federal Register, December 23, 1971). In order to perform Method 5, Methods 1 through 4 must also be used. Subpart A of 40 CFR 60 requires that affected facilities which are subject to standards of performance for new stationary sources must be constructed so that sampling ports adequate for the required performance tests are provided. Platforms, access, and utilities necessary to perform testing at those ports must also be provided.

Sampling costs for performing a test consisting of three Method 5 runs is estimated to range from $5,000 to $9,000. If in-plant personnel are used to conduct tests, the costs will be somewhat less.

The recommended performance test method for visible emissions is Method 9 (Appendix A, 40 CFR 60, Federal Register, November 12, 1974).

REFERENCES

1. Schwarzkopf, F., Lime Burning Technology, Kennedy van Saun Corp., 1974.

2. Turkdogan, E. T. and B. B. Rice, "Desulfurization of Limestone and Burnt Lime" Transactions AIME v254 p.28 March 1973.

3. Wrudt, H. A. and L. S. Darkin, "Equilibrium of Sulfur Bearing Gases and Solids Revelant to the Burning of Limestone; Transactions AIME, v254 p.1 March 1973.

APPENDIX E

IMPACT CALCULATIONS

The additional control potential of new or revised standards of performance stems from the application of emission standards that are more stringent than those presently applied to construction and modification. This (impact) for a specified time period, is expressed as

$$(T_S - T_N)$$

Where: T_S = Emissions per year under baseline year control regulations

T_N = Emissions per year under new or revised standards of performance.

To calculate the control potential of control options other factors must be considered, such as the portion of growth requirements that can be satisfied from present unused capacity and the obsolescence and replacement rates of existing facilities. Such a comparison can be expressed mathematically.

The following notation is used in the development of the relationship between projected emissions under baseline year (1976) regulations and the control options.

T_S = total emissions in 1986 year under baseline year regulations (tons/year)

T_N = total emissions in 1986 with control options adopted in 1976. (tons/year)

K = normal fractional utilization rate of existing capacity, assumed constant during time interval

B = production capacity from construction and modification to replace obsolete facilities (production units/yr)

C = production capacity from construction and modification to increase output above baseline year capacity (production units/yr)

E_S = allowable emissions under existing regulations (mass/unit capacity) for new construction

E_N = allowable emissions under control option (mass/unit capacity)

$T_s - T_n = K (B + C) (E_s - E_n)$

I. For Rotary Lime Kilns -- Particulate Emissions

From Chapter 7, Table 7-6

$K = 0.893$

$B + C = 16{,}522{,}000$ tons lime/year (1987)

$B + C = 14{,}985{,}000$ megagrams lime/year (1987)

1. For Options A-1 and B-1 (described in 6.1.1)

   From Table 6-2

   $E_n = 0.030$ kg/Mg lime (0.60 lb/t lime)

   $E_s = 1.00$ kg/Mg lime (2.00 lb/t lime)

   $E_s - E_n = 0.70$ kg/Mg lime (1.40 lb/t lime)

   $T_s - T_n = K\ (B + C)\ (E_s - E_n)$

   $T_s - T_n = 0.893\ (14{,}985{,}000)\ (0.70)$

   $T_s - T_n = 9{,}370{,}000$ kg/year

   $T_s - T_n = 9{,}370$ megagrams/year (10,330 tons/year)

2. For Options A-2 and B-2 (described in 6.1.1)

   From Table 6-2

   $E_n = 0.50$ kg/Mg lime (1.00 lb/t lime)

   $E_n = 1.00$ kg/Mg lime (2.00 lb/t lime)

   $E_s - E_n = 0.50$ kg/Mg lime (1.00 lb/t lime)

   $T_s - T_n = K\ (B + C)\ (E_s - E_n)$

   $T_s - T_n = 0.893\ (14{,}985{,}000)\ (0.50)$

   $T_s - T_n = 6{,}690{,}000$ kg/year

   $T_s - T_n = 6{,}690$ megagrams/year (7376 tons/year)

II. For Lime Hydrators -- Particulate Emissions

From Chapter 7, Table 7-6

$K = 0.84$

$B + C$ = 775,000 tons hydrate/year (1987)

$B + C$ = 703,000 megagrams hydrate/year (1987)

For the Control Option described in 6.2.1

E_n = 0.06 kg/Mg hydrate (0.12 lb/t hydrate)

E_s = 0.40 kg/Mg hydrate (0.80 lb/t hydrate)

$E_s - E_n$ = 0.34 kg/Mg hydrate (0.68 lb/t hydrate)

$T_s - T_n = K (B + C) (E_s - E_n)$

$T_s - T_n = 0.84 (703{,}000) (0.34)$

$T_s - T_n$ = 201,000 kg/year

$T_s - T_n$ = 201 megagrams/year (221 tons/year)